Rocky Mountain National Park

Nitrogen Deposition Reduction Plan

Memorandum of Understanding
Agencies

National Park Service
Environmental Protection Agency, Region VIII
Colorado Department of Public Health & Environment

Draft Plan

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I. Executive Summary

Rocky Mountain National Park (RMNP) is one of the crown jewels of the National Park System. Established by Congress in 1915, the Park is recognized worldwide as an outstanding scenic area and national treasure. The Park is a unique area containing high alpine ecosystems and tundra above the treeline, mountain valleys and meadowlands, glaciers, alpine lakes and streams, vast forested areas, and abundant wildlife. Two protected native trout species, the greenback cutthroat trout and the Colorado River cutthroat trout, are unique to the east and west sides of the Continental Divide in the Park, respectively. The Park is an exceptional and spectacular example of these and other attributes, and most of its roughly quarter million acres are managed as wilderness.

The National Park Service (NPS), other federal agencies, and academic researchers have actively pursued ecosystem and air quality monitoring and data collection programs in and near the Park for over twenty years. Through these efforts significant amounts of data have been collected. Findings from these data published in over 80 peer reviewed research articles document ecosystem changes from nitrogen (N) deposition on the east side of the Continental Divide including changes in the type and abundance of aquatic plant species, elevated levels of nitrate in surface waters, elevated levels of N in spruce tree chemistry, long-term accumulation of N in forest soils, and a shift in alpine tundra plant communities favoring sedges and grasses over the natural wildflower flora. Two-thirds of the Park is near or above treeline with shallow soils and granitic bedrock that are indicative of a fragile ecosystem environment. This environment is highly susceptible to changes induced by chemical contributions to soils and waters through atmospheric deposition.

The Park's enabling legislation and other key Congressional statutes mandate that natural resources at RMNP are to remain unimpaired for future generations. Thus, the Rocky Mountain National Park Initiative was created to study and promote action to remedy air quality issues facing the Park, primarily the adverse ecosystem impacts from increasing nitrogen deposition. Other air quality issues are being addressed by other means: visibility impairment by the regional haze program development and ozone by the early action compact process.

Using a collaborative approach, the participating agencies -- the Colorado Department of Public Health and Environment (CDPHE), the U.S. Environmental Protection Agency Region 8 (EPA), and the NPS -- have worked effectively to develop this Nitrogen Deposition Reduction Plan (Plan or NDRP). A public participation process facilitated by a Colorado Air Quality Control Commission (AQCC) Subcommittee has helped to involve the public, and a memorandum of understanding (MOU) has been used by the involved agencies to guide the Initiative's progress leading to development of this Plan (Chapter II).

The agencies have initially focused their efforts in developing the Plan on voluntary approaches first, together with programs that are pending or under way, in lieu of developing a new regulatory program to achieve nitrogen deposition reductions. The agencies believe this strategy has the potential to provide benefits in the near term to reducing nitrogen deposition. However, the agencies support a process to require regulatory measures specific to reducing nitrogen deposition if voluntary and anticipated reductions prove insufficient in making planned progress goals under this Plan. Development and implementation of a contingency plan is one mechanism supported by the agencies to ensure reduction of adverse ecosystem impacts in RMNP.

The NDRP works to: (1) consider all available emission reduction options and programs for nitrogen-related emissions (primarily nitrogen oxides (NOx) and ammonia (NH3)); (2) provide a technical assessment of the state-of-knowledge of deposition components and trends, the emission sources, source areas, and atmospheric transport; (3) determine implementation measures for making progress and mechanisms to evaluate effectiveness of, and incorporation of new, control measures; (4) make recommendations for future needs as necessary to assure continued progress and achievement of Park goals; and (5) incorporate adaptive management principals for the consideration and use of new data and analyses as they become available.

The NDRP identifies planned regulatory actions that will reduce nitrogen deposition in the Park, significant actions that have been taken during the discussions and development of this Plan, and a process to define future direction and progress for reducing nitrogen deposition in the Park. This NDRP relies in part on planned emissions reductions from state and federal programs for Regional Haze to reduce oxides of nitrogen from stationary industrial sources in Colorado and surrounding states. NOx reductions from the application of BART in Colorado are expected to achieve XXXX tons per year of emissions reductions. New car engine and emission control system requirements are also anticipated to achieve a XX% reduction of mobile source NOx by 20XX. The Plan anticipates that the implementation of these programs in other western states will provide an added benefit to reducing nitrogen deposition in RMNP.

The Plan includes a critical load determination for nitrogen affecting the high alpine ecosystems in the Park that was established prior to the development of this Plan. The critical load for wet nitrogen deposition, set at 1.5 kg/ha/yr, is a threshold value above which significant harmful effects to sensitive ecosystem components occur. The critical load for wet nitrogen deposition east of the Continental Divide in RMNP represents an estimation of the concentration at which excess nitrogen deposition began causing harmful impacts on RMNP ecosystems (Chapter III). The Plan relies on a “glidepath” management approach to achieve the critical load goal in the Park by the year 2032 with interim milestones to be measured at five-year intervals (Chapter IV). The first milestone, set for 2012, works to achieve a reduction that is consistent with an average rate of deposition reduction that will achieve the critical load by the year 2032 and reflects the potential benefit from planned state and federal emission reduction programs.

The Plan identifies potential emission control options and air quality management frameworks to reduce nitrogen compound emissions (Chapter V).). The MOU agencies will use an adaptive management approach to consider these and potentially other control options for implementation as new and refined information increases our understanding of their viability and effectiveness. Incorporation of feasible control measures into a future contingency plan or a specific regulatory program for nitrogen deposition reduction will be conducted through a public participation process for adoption by the appropriate State regulatory commission.

The primary emissions of nitrogen deposited in the Park are from sources of oxides of nitrogen and ammonia, so the emission reduction options focus on NOx emission reduction strategies and ammonia emission reduction strategies. Oxides of nitrogen are combustion products, primarily generated from the burning of fossil fuel. Therefore, these strategies focus on the emissions of NOx from large and small stationary industrial sources and mobile sources. Ammonia is generated primarily from a variety of agricultural practices, including animal husbandry, as well as natural processes. Therefore, these strategies focus on ammonia emissions from agricultural sectors, including but not limited to livestock operations and application of fertilizers. The use and impact of urban fertilizers is currently unknown and subject to future research efforts. Emission inventories of ammonia from agricultural practices are widely considered to be inaccurate, and mitigation measures that can reduce these emissions may require additional research to better gauge their effectiveness. A combination of both voluntary and regulatory approaches to management of these emission sources has the potential for reducing nitrogen deposition in accordance with the glidepath goals set forth in this Plan.

The extent to which voluntary emission reductions are promoted and implemented may be key to the need for future regulatory approaches. Existing regulatory programs that will provide nitrogen deposition reductions are primarily concerned with nitrogen oxide emissions that contribute to ozone formation and regional haze. However, these emissions are responsible for roughly half the nitrogen deposition in the Park, with ammonia emissions contributing the rest. The Park itself and nearby areas are engaging in multiple voluntary emission reduction programs for implementation that should help to reduce nitrogen deposition in the Park. These strategies largely focus on mobile and stationary source emission reduction approaches. The Plan also acknowledges that emissions from natural sources in the Park should be similar to conditions occurring historically prior to excess nitrogen deposition amounts now affecting RMNP (Chapter VI).

The NDRP contains several key foundational components for meeting the responsibilities of the signatory agencies under the MOU and for meeting the direction given by the AQCC Subcommittee. The foundation of the Plan includes:

- Reversing the trend of increasing nitrogen deposition in RMNP over a 25 year period using a glidepath approach with interim milestones/goals measured at 5 year intervals to achieve the wet nitrogen deposition critical load of 1.5 kg /ha/yr.

- Implementing emission reduction options first (e.g., best management practices for the agricultural sector, emission reduction measures in and near the Park, and pollution prevention programs), together with programs that are pending or under way, to achieve the resource management goals established by the Park and agreed to by the agencies, before looking to new regulatory approaches.
- A commitment to continued research and monitoring to refine understanding of the sources and attribution of nitrogen deposited in the Park, as well as controls.
- Adoption of NOx emission reduction strategies for the Regional Haze SIP revision by the end of 2007, and consideration of deposition goals to the extent possible in the Denver area Ozone Action Plan and other relevant air quality planning.
- Adaptive management principles, including contingency planning, to assure continued long-term effectiveness of the Plan to achieve the resource management goal for nitrogen deposition in RMNP.
- Continuation of a collaborative approach to successfully address the nitrogen deposition issue, but individual agency responsibilities are also respected.

In carrying this Plan forward, the MOU agencies will work together to achieve the first and subsequent milestones for reducing deposition in RMNP. Many steps are necessary to ensure progress is made, including: reviewing and incorporating additional data and analyses, tracking and assessing deposition in the Park and planned emission reductions, promoting development and implementation of voluntary best management practices for ammonia emission reductions, creating databases that assure better accountability for emissions of ammonia and nitrogen oxides, development of a contingency plan to provide certainty for achievement of deposition goals, and engaging stakeholders and the concerned public to assist in the process of review and selection of emission control strategies. The Plan also recognizes that each MOU agency individually has mandates and responsibilities to their agency's missions and goals and that they may be taking separate steps and measures, to that end, which may be related to the overall purposes of this Plan (Chapter VII).

II. Background and Purpose

A. History of Concern

Rocky Mountain National Park (RMNP) was established by Congress in 1915 and is recognized as an outstanding scenic area and natural treasure. RMNP encompasses over 265,780 acres, 350 miles of trails, and hosts 3 million visitors from around the world annually. Meadows, forests, mountain peaks, tundra, alpine lakes and streams, wildlife, and glaciers are all a part of the Park's unique natural landscape. Two-thirds of the Park is near or above treeline, creating fragile high-elevation ecosystems that park managers are responsible for protecting.

The National Park Service (NPS) is mandated by Congress to maintain and preserve natural conditions at RMNP for future generations. The 1915 Rocky Mountain National

Park Organic Act that established RMNP and states that the Park is: "…for the benefit and enjoyment of the people of the United States….and for the preservation of the natural conditions and scenic beauties thereof." Also, the NPS Organic Act (1916) directs the NPS "…to promote and regulate the use of the….national parks…which purpose is to conserve the scenery and the natural and historic objects and the wildlife therein and to provide for the enjoyment of the same in such manner and by such means as will leave them unimpaired for the enjoyment of future generations." Similarly, the Wilderness Act (1964) secures certain federally owned areas designated by Congress as wilderness areas "for the use and enjoyment of the American people in such a manner as will leave them unimpaired for future use as wilderness." Ninety-five percent of RMNP is managed as wilderness. Finally, the Prevention of Significant Deterioration Program (Clean Air Act Amendments of 1977) sets out a goal to "preserve, protect, and enhance the air quality in national parks, national wilderness areas, national monuments, and national seashores, and other areas of special national or regional natural, recreational, scenic, or historic value." Congress also declared as a "national goal the prevention of any future, and the remedying of any existing, impairment of visibility in mandatory Class I federal areas which impairment results from manmade air pollution." RMNP is classified as a Class I air quality area as defined by the Clean Air Act that provides for the least amount of air pollution degradation.

The importance of atmospheric nitrogen (N) deposition relative to the natural processes and natural character of RMNP has become better understood over time, as scientific research and monitoring that began in the early 1980's have documented various changes to ecosystems in the Park due to N deposition. The changes include forest and soil biogeochemical changes, enhanced microbial activity in soils, increased N in Park lakes and streams, changes in surface water chemistry, altered tree chemistry, and shifts in species of aquatic plants. These changes are discussed in more detail in Chapter III. Eighteen years of monitoring data show that the Park is experiencing increased N deposition levels in high elevation ecosystems. The current levels of N deposition are almost 20 times the natural background or pre-industrial levels. Nitrogen deposition trends are discussed in Chapter VI. Native trout and alpine wildflowers, two of the Park's most unique resources, will likely be harmed if N deposition levels remain the same or increase. Based on the most recent information regarding N deposition, in 2004 a multi-agency meeting including the Colorado Department of Public Health and Environment (CDPHE), the NPS, and the U.S. Environmental Protection Agency (EPA) was held to address the effects and trends of N deposition in the Park, as well as related air quality issues including ozone standard exceedences and visibility impairment. These agencies agreed to pursue a more in-depth review of the issues and a course of action to address them.

Later that year, the U.S. Department of the Interior was petitioned by Environmental Defense and Colorado Trout Unlimited to immediately declare adverse affects on Air Quality Related Values (AQRV's) at RMNP and to promptly establish a critical load for N deposition that would protect Park ecosystems. The petition (available at http://www.cdphe.state.co.us/ap/rmnp/petition.pdf) also called for the U.S. EPA and the State of Colorado to fulfill their legal responsibilities to lower emissions of nitrogen oxides and ammonia to protect human health, plants, ecosystems, and scenic vistas at RMNP. Rather than pursue an adversarial approach to this issue suggested by the petition, the affected agencies decided to continue with the collaborative approach of action already underway to develop effective yet realistic solutions to the harm being caused to the ecosystem at RMNP.

B. The Rocky Mountain National Park Initiative

The interagency effort to address issues of adverse air quality in RMNP has been termed by the three primary involved agencies – CDPHE, EPA, and NPS – the “Rocky Mountain National Park Initiative”. While impaired visibility and elevated ozone levels are air quality concerns at RMNP and have been the subject of some discussion within the Initiative, the Nitrogen Deposition Reduction Plan is focused on the nitrogen deposition issue. Ozone is being addressed in the Early Action Compact process, and visibility is being addressed in the regional haze process. The Initiative will continue to monitor these issues as they affect RMNP.

Initial discussions among the involved agencies followed several briefings at Colorado Air Quality Control Commission meetings by the NPS since 1998 on relevant findings from the Park’s long-term research and monitoring programs. These discussions served to develop a common understanding of the issues, the options to address the issues and the technical basis of the N deposition concerns at RMNP. As progress was made in reaching a mutual understanding of the issues, a special subcommittee of the Colorado AQCC, co-lead by Commissioners Bob Brady and Jim Martin, was established which provided a forum for continued discussions and allowed public participation in the process.

In December 2005, NPS, CDPHE and EPA signed a Memorandum of Understanding (MOU) “For Interagency Collaboration to Address Air Quality Issues Affecting RMNP”, with the goal of facilitating timely development and implementation of air management policies and programs to reverse the trend of increasing nitrogen-related compound impacts affecting RMNP. To further this goal, the Initiative’s work includes assessment of the technical data and information relevant to N-related air quality issues affecting RMNP. Consideration of the effects of N compound emissions reductions on visibility, ambient ozone levels, and N deposition in the Park will be part of the State’s planning effort as these programs are developed and modified in the future. The MOU has fostered cooperation and communication among the lead agencies and helped them to work efficiently and effectively together toward the common goal of understanding the problems and developing a practical working approach to address the ecosystem issues in RMNP.

The work of the RMNP Initiative is guided by a Steering Committee and is accomplished by several working teams including an Air Technical Team, Water Team, an Agricultural Team, the Colorado AQCC and members of the public (Figure II.1). The teams are staffed by agency representatives and include individuals with specialized expertise. The teams provide technical information to the Steering Committee, and the Steering

Committee is responsible for briefing the AQCC Subcommittee and members of the public to solicit input at regularly scheduled meetings. CDPHE hosts the RMNP Initiative website (http://www.cdphe.state.co.us/ap/rmnp.html) where presentations, documents, and reports are available.

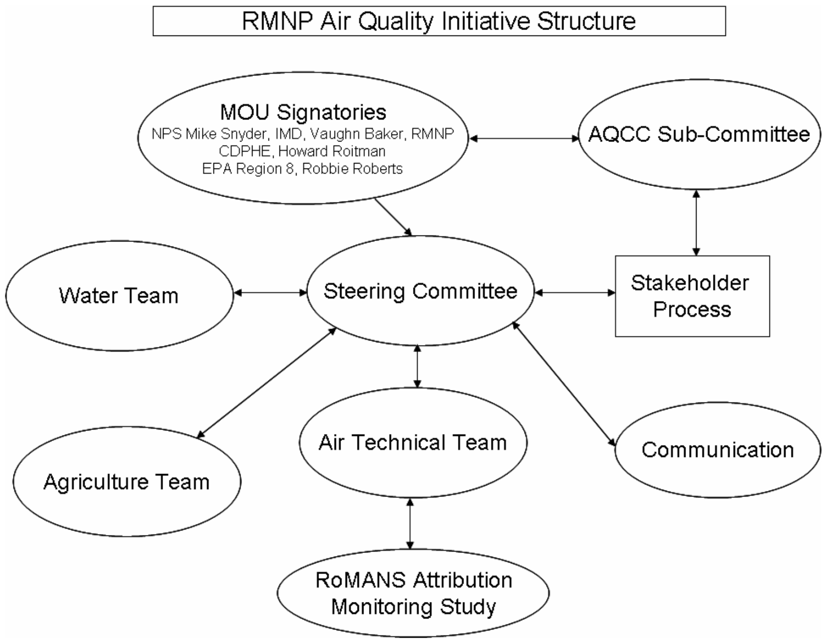

Figure II.1. RMNP Initiative Structure.

The RMNP Initiative has made progress under the terms of the MOU by RMNP's development of a N-related resource management goal for high-elevation ecosystems east of the Continental Divide based on a long-term body of scientific research and site-specific monitoring data in the Park (see Chapter III of this Plan for details). Establishment of this resource management goal helps to define the future direction and progress for reducing N deposition at RMNP and is substantially lower than the current level of observed deposition in the Park. The AQCC Subcommittee held several public meetings at which the technical basis for the Park's goal determination was presented and discussed. CDPHE and EPA support the Park's findings.

The RMNP Initiative Steering Committee developed potential management approaches to address achievement of Park resource management goals and presented these publicly to the AQCC Subcommittee. The AQCC Subcommittee, with substantial input and agreement from the participating members of the public, directed the RMNP Initiative to develop a Nitrogen Deposition Reduction Plan (NDRP) as the next step in making progress toward the goal of the MOU. Concurrent to the development of the NDRP, existing information on deposition composition and trends, emissions inventories and analyses that could inform the emissions-deposition relationship has been examined (Chapter VI), to determine potential source categories and source areas that are likely contributing to N deposition in the Park.

The Steering Committee worked to coordinate the efforts of the individual teams and often participated in the team activities on a regular basis. Individual team members and members of the Steering Committee worked to draft individual sections of the Plan and the document was assembled for internal review. Once a first draft was rendered, the draft document was shared with the members of the public through review in the AQCC Subcommittee process. Through the Subcommittee process initial public comment was solicited and the draft version of the document was revised. The second draft of the document was then formally set out for public comment opportunity and presented to the Commission. The agencies solicit the approval of the Plan by the AQCC, but believe the document will need to be revised following the Commission’s scheduled public hearing to incorporate the added public comments received.

C. Purpose

The purpose of the RMNP Nitrogen Deposition Reduction Plan is to describe the actions and results of work done under the RMNP Initiative to date and to develop a set of options that can be implemented to address ecosystem impacts from air pollutant deposition in the Park. The RMNP Initiative has been a two year process by which State and Federal governmental agencies are working with interested members of the public to study and take action on air quality issues facing the Park. The purpose of the Plan is to focus the collaborative process first on the voluntary implementation options then to provide a forum for determining the most efficient and cost effective options within the legislative/regulatory process to achieve the resource management goal for the Park. The Plan sets forth 1) a strategy to achieve the goal, 2) a set of options that can be implemented on a voluntary or required basis, and 3) a timeline and set of interim milestones to achieve the resource management goal and restore ecosystem health in RMNP.

III. Ecosystem Effects due to Nitrogen Deposition and Critical Load for Rocky Mountain National Park

A. Summary of Ecosystem Effects due to Nitrogen Deposition

Nitrogen compounds carried in air currents and deposited in ecosystems can act as a growth enhancing fertilizer, favoring some types of plants and leaving others at a disadvantage. Nitrogen compounds also have acidifying properties that can strip natural buffering agents from sensitive soils and waters, leaving ecosystems vulnerable to acidification. These changes create an imbalance in natural ecosystems, and long-term effects may be profound as species shifts occur and ecosystem processes are disrupted.

High-elevation ecosystems in the Park are more vulnerable to atmospheric N deposition than many ecosystems in the eastern U.S. or in other countries. This vulnerability is due to several factors. First, the granitic bedrock and shallow soils found in the Park do not provide much chemical buffering. Second, short growing seasons at high-elevation limit the amount of time plants have to absorb N for growth during the year; these plants evolved under very low N conditions, so they are more adapted to N impoverishment rather than N enrichment.

The effect of N in ecosystems is different depending on whether nitrate or ammonium is deposited. Ammonium deposition has a greater potential than nitrate for producing harmful changes in ecosystems because ammonium by-products cause greater changes in plant growth and insect vulnerability and they produce an extra acidifying effect in soils during the biological conversion from ammonium to nitrate.

Researchers from the U.S. Geological Survey (USGS), Colorado State University and the NPS have been working for over 20 years to determine if air pollution is affecting high-elevation ecosystems in RMNP. Sufficient data exist to demonstrate that soils, waters, and plants show evidence of changes due to atmospheric N deposition. More than 80 peer-reviewed journal articles have been published on various aspects of the biogeochemistry and ecology of high-elevation ecosystems in the Colorado Front Range, including RMNP. Most of these articles can be found at http://www.nrel.colostate.edu/projects/lvws/pages/publications/publications.htm.

Additional information detailing ecosystem effects, including the Technical Background Document, "Nitrogen Deposition: Issues and Effects in Rocky Mountain National Park (2004)" is available on the RMNP Initiative website (http://www.cdphe.state.co.us/ap/rmnp.html).

RMNP is bisected from north to south by the Continental Divide, creating a west and an east side of the Park (Figure III.1.). Much of the published research documents ecosystem changes from N deposition on the east side of the Continental Divide. Briefly, these unnatural effects include:

> (1) Changes in both the type and abundance of aquatic plant species (diatoms). This indicates a shift from naturally occurring plant species in undisturbed, oligotrophic (low-nutrient) lakes towards nutrient-tolerant plant species indicative of disturbed systems and eutrophication (over-fertilization);
>
> (2) Chronically elevated levels of nitrate in surface waters. Accumulation of nitrate in East Side Park waters indicates advanced stages of N saturation - nitrate levels are "stage 2+" on a widely used N saturation scale of zero to three. N

saturation effects are negligible at stage "zero" and declines in ecosystem health (such as increased mortality of trees and fish) are more likely as stage 3 is reached;

(3) Elevated levels of N in spruce tree chemistry. This indicates an imbalance of essential nutrients and an increased risk of declining forest resistance to disease, insect infestation, drought, and cold temperatures; and

(4) Long-term accumulation of N in forest soils. Soil N at current elevated levels has increased soil microbial activity, which further increases N production. As such, accumulating N from atmospheric deposition is fueling a cycle of increasing N concentrations in Park soils and surface waters.

In addition, a recent publication in 2006 in the journal *Ecological Applications* by Dr. William Bowman, a University of Colorado researcher, shows that a shift in alpine tundra plant communities favoring sedges and grasses is occurring on Niwot Ridge, just outside Park boundaries. This research indicates that N deposition at high-elevations in the Park is sufficient to bring alpine ecosystems to a tipping point for significant change from N deposition that would not be likely to reverse for hundreds, or in some cases, thousands of years. Research in other areas of the U.S. supports concerns that this could lead to reductions in alpine wildflowers in the Park.

Studies of ecosystem changes with increasing deposition in the eastern U.S. and Europe suggest that changes in soils, waters, plants and animals in RMNP are likely to become more severe if elevated N deposition continues to occur. Even if N deposition remained at current levels, N would continue to accumulate in high-elevation Park soils. In addition, N deposition has been shown in mountain ecosystems in other areas to use up natural buffering chemicals in lakes and soils, until they eventually become acidic and cease to support sensitive aquatic species, including fish. Ecosystem models are being employed to determine how long it would take, at current and elevated rates of N deposition, for this to occur in RMNP.

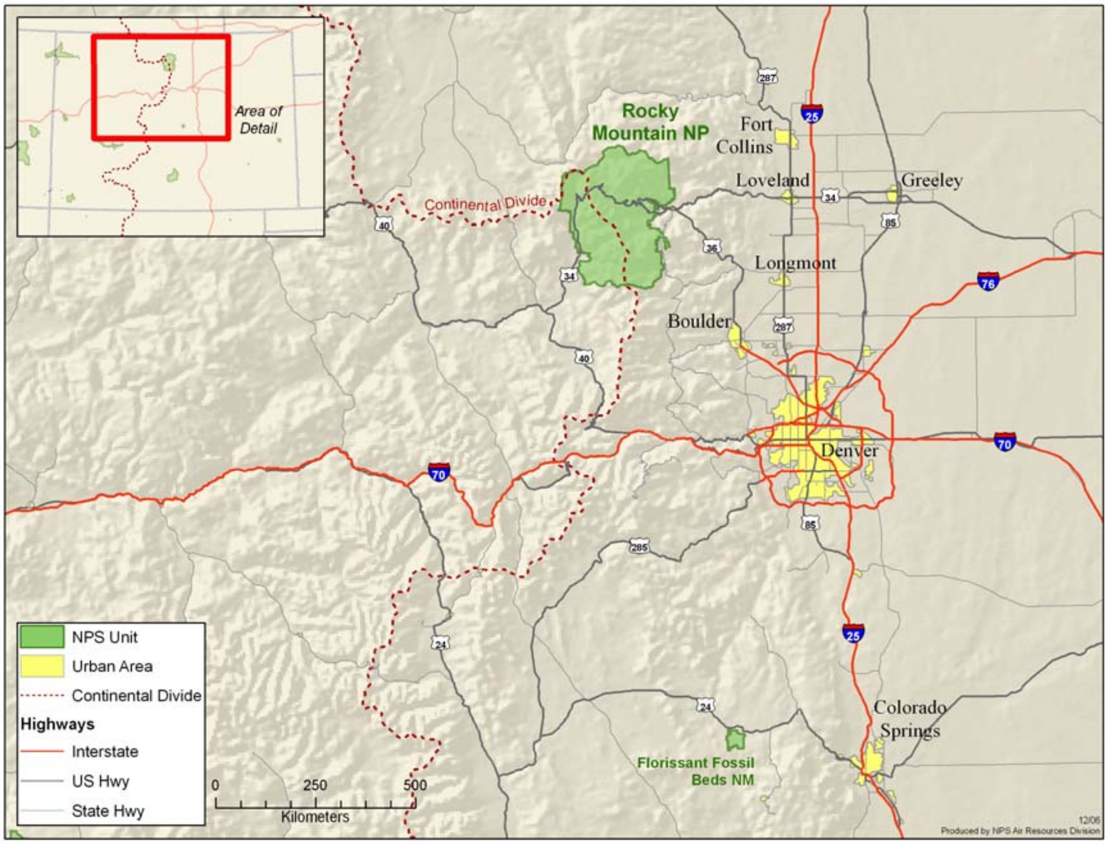

Figure III.1. Map of RMNP in Colorado.

B. Summary of Nitrogen Deposition in Rocky Mountain National Park

Airborne nitrogen compounds are deposited to ecosystems in wet (rain and snow) and dry (particle and gas) forms. Long-term monitoring data from the National Atmospheric Deposition Program (NADP) and the Clean Air Status and Trends Network (CASTNet) are used to report deposition in RMNP. Data from the high-elevation Loch Vale NADP site (3159 m) in the Park is used to characterize wet deposition, as the most deposition-sensitive ecosystems in the Park are also at high-elevations. The CASTNet site (2743 m) is on the east side of the Park and is used to characterize dry deposition. Deposition is reported in terms of kilograms of N per hectare per year (kg N/ha/yr). Current wet inorganic N deposition is estimated at 3.1 kg N/ha/yr, based on a 5-year average (2000-2004).[1] Current dry inorganic N deposition is estimated at 0.9 kg N/ha/yr, based on a 5-

[1] The NADP has approved two new raingages for use in the network and requires that all monitoring sites have a new raingage by 2009. The NADP is also testing modifications to the precipitation collector that will improve snow collection efficiency. These equipment upgrades may result in changes to wet deposition estimates.

year average (2000-2004). Total inorganic N deposition in the park can be estimated by adding wet and dry deposition for a total of 4.0 kg N/ha/yr. This is the best estimate of total inorganic N deposition to high-elevation ecosystems in the Park. Pre-industrial or "natural" levels of N deposition are estimated to be about 0.2 kg/ha/yr or approximately 20 times lower than current deposition. Spatial patterns and trends in deposition are discussed further in Chapter VI, "Current Knowledge of Emissions, Transport and Deposition."

C. Critical Load Concepts and Current Efforts

Critical loads are measures used to quantify harmful pollution levels and to set goals for resource protection or restoration on federal lands. Exceeding critical loads for N can cause ecosystem N saturation, biotic community changes, or acidification. A critical load is often expressed as an amount of deposition required to induce a change to a chemical, physical, or biological indicator. More specifically, a critical load has been defined as "the quantitative estimate of an exposure to one or more pollutants below which significant harmful effects on specified sensitive elements of the environment do not occur according to present knowledge."[2]

Critical loads are based on science; however air quality managers may establish target loads that represent a policy decision about the amount of deposition that could be allowed within a certain time frame without jeopardizing resource protection. Target loads may be higher or lower than critical loads. For protected Federal lands in the U.S., land managers recommend that target loads be set lower than the critical load to provide an adequate margin of safety in preventing damage to ecosystems. For areas where the critical load has been exceeded, one or more "interim" target loads that are higher than the critical load may be selected as benchmarks for assessing progress. Target loads are based on political, economic, and social considerations, in addition to resource protection and restoration concerns.

The critical load concept has been widely adopted in Europe as a tool for integrating information about the effects of air pollution on ecosystems, land management objectives, and regulation of atmospheric pollution. The United Nations Economic Commission for Europe, Convention on Long-Range Transboundary Air Pollution (Working Group on Effects), has established International Cooperative Programmes (ICPs) to address the effects of air pollution on ecosystems, human health, and cultural resources across Europe. Information from ICP monitoring of forests, waters, and natural vegetation has been used to calculate critical loads, set target loads, and support emission control policies throughout Europe. In Europe, acidified lakes and streams have shown signs of recovery: "calculations show that the deposition in excess of critical loads of acidification has been greatly reduced in Europe due to emissions reductions."[3]

[2] Nilsson, J., Grennfelt P. (eds.) 1988. *Critical Loads for Sulphur and Nitrogen*. Copenhagen (Denmark): Nordic Council of Ministers.
[3] 2004, *Review and Assessment of Air Pollution Effects and Their Recorded Trends.* United Nations Economic Commission for Europe, Working Group on Effects. Geneva, Switzerland.

In the U.S., in response to recommendations by the National Academy of Sciences and the Clean Air Act Science Advisory Committee, the U.S. EPA has been exploring the use of critical loads as an assessment tool in general and in the regulatory process,[4] and has participated in several projects exploring critical loads issues including modeling, mapping, developing pilot projects and synthesizing the state of the science on indicators and monitoring ecosystem response to air pollution (http://www.epa.gov/airmarkets/cmap/linkdescs/) (http://epa.gov/air/caaac/aqm.html).

Critical loads are: (1) specific to an individual park or other ecosystem; (2) protect the most sensitive resources within each federal area; and (3) are based on the best science available. They document the deposition loading at which ecosystem changes begin to occur and can be used as a starting point for policy discussions and decisions regarding desired levels of deposition reductions over time, or target loads.

D. Critical Load Determination for Rocky Mountain National Park

Recently published research indicates that ecosystem health began to decline at high-elevation areas on the east side of RMNP between 1950 and 1964 due to excess N when a shift in aquatic biota from a natural to a disturbed condition occurred. Park managers determined that this shift, and the other physical and chemical changes that occurred following this shift, constitute significant harmful effects on Park ecosystems east of the Continental Divide. To determine a critical load for aquatic ecosystem health, deposition levels at the time the changes occurred were assessed. During the 1950 to 1964 time period, based on hindcasting from current deposition estimates, the average wet deposition has been estimated as 1.5 kg N/ha/yr (a 52 percent reduction from current wet N deposition). This critical load only applies to wet deposition of N compounds because the monitoring techniques are proven and sound and the historical data record for wet deposition is robust; allowing reasonable estimates for historical wet deposition to be made. Dry deposition monitoring techniques are less reliable. So while critical loads would ideally be estimated for total deposition, in this case, a wet deposition critical load is adequate because the proportion of wet to total is likely to be similar throughout the period of record. Therefore, if the wet N deposition critical load is achieved, then dry N deposition rates should also decline.

The critical load defining the thresholds for aquatic ecosystem changes due to eutrophication (excess nitrogen) at RMNP (1.5 kg N/ha/yr), is about half the current level of wet N deposition at the Loch Vale monitoring site on the east side of RMNP (3.1 kg N/ha/yr) . The critical load value is similar to deposition levels measured in Colorado on the west side of the Continental Divide, where ecosystems are relatively healthy.

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http://www.unece.org/env/lrtap. Terrestrial systems take longer to recover because pollutants accumulating in soils remain for decades or centuries.

[4] U.S. EPA revised the NO_2 Increment Rule under the Prevention of Significant Deterioration program to provide an opportunity for states and federal land managers to implement critical loads pilot projects to address ecosystem effects from N deposition, which "could lead to implementation plans that demonstrate protection against deterioration of AQRVs from N impacts . . . ." (October 12, 2005).

Additional information on the development of this critical load value can be found in the paper recently published by Dr. Jill Baron, USGS, in the journal *Ecological Applications* 2006, titled "Hindcasting Nitrogen Deposition to Determine an Ecological Critical Load."

Current research also demonstrates that alpine ecosystems in the Park are at a tipping point for dramatic ecological change, where grasses may begin to out-compete wildflowers. Alpine ecosystem scientists estimate that a rapid reduction in wet N deposition from current conditions to 2.7 kg N/ha/yr (a 13 percent reduction from current wet N deposition) would slow accumulation of N in soils, and thus protect alpine plant communities from N-induced change. Immediate reductions in N deposition would also mitigate the chance of future acidification of Park surface waters that could result in concurrent losses of fish and other aquatic biota.

As N deposition is reduced to the critical load and possibly below this level, aquatic ecosystems on the east side of the Park are expected to return to a healthy natural condition similar to the condition of these sites prior to 1950 and to ecosystems on the west side of the Park. As N deposition decreases, significant improvement in ecosystem health should occur over the next few decades in RMNP because these high-elevation ecosystems are in the early stages of unnatural change. In contrast, research indicates that highly impacted ecosystems in the eastern U.S. may take centuries to recover from the effects of atmospheric deposition because of the buildup of pollution in soils.

IV. The Nitrogen Deposition Reduction Plan (NDRP)

This chapter discusses the development of a resource management goal for RMNP and makes recommendations for achieving that goal.

A. The Resource Management Goal

The MOU signed by CDPHE, U.S. EPA and NPS establishes the following goal:

> [T]o facilitate timely development and implementation of air management policies and programs, as determined necessary, to reverse the trend of increasing nitrogen-related compound impacts affecting Rocky Mountain National Park.

The MOU also commits RMNP to "Define resource management goals related to N deposition (e.g., critical loads, sustainable conditions, desired future conditions) that would be protective of the Park's sensitive resources." RMNP undertook this effort based on responsibilities mandated by the Clean Air Act, the Wilderness Act, and the NPS Organic Act of 1916. Accordingly, federal land managers are responsible for determining what to protect and the degree of protection to provide on federal lands. (See Chapter II).Moreover, the 1915 enabling legislation for RMNP states that it was set aside "for the preservation of the natural conditions and scenic beauties" contained therein.

RMNP has worked with the U.S. Geological Survey research Scientist, Dr. Jill Baron, to conduct an analysis to determine the critical load based on data that had been collected and the decades of research performed in the Park. Dr. Barron published the results of her analysis in the journal *Ecological Applications* in April, 2006.[5] Dr. Baron's results identify the critical load defining the thresholds for aquatic ecosystem changes due to eutrophication (excess nitrogen) at RMNP to be 1.5 kg N/ha/yr. RMNP adopted the 1.5 kg N/ha/yr wet deposition as an appropriate science-based threshold for identifying adverse ecosystem effects in the Park, and stated that it is the "benchmark that should be used at this time to link ecosystem protection goals of RMNP with air, and possibly water, management programs and policies administered by the State." This resource protection value was communicated to the U.S. EPA and the CDPHE and supported by those agencies in subsequent correspondence. Correspondence between the agencies is available at http://www.cdphe.state.co.us/ap/rmnp.html.

B. The Glidepath Approach

The RMNP Initiative has selected the glidepath approach for achieving the resource management goal. This approach, which is modeled after the regional haze planning process, anticipates gradual improvement over time and is an accepted regulatory/policy structure for long-term, goal-oriented air quality planning. Significant infrastructure for this approach already exists within the State with regional and national support.

The glidepath approach incorporates the Park's resource management goal, the target year for achieving the goal, and interim target loads for evaluating progress as discussed below.

C. Target Year to Achieve the Resource Management Goal

The RMNP Initiative Steering Committee considered three scenarios in developing a timeframe for achieving the resource management goal for RMNP. These scenarios are based on regulatory models currently being used to improve air quality. As illustrated in Figure IV.1., glidepath options are shown with target years of 2018, 2032, and 2064 (years in which the resource management goal should be achieved)

[5] Baron, J. (2006). "Hindcasting Nitrogen Deposition to Determine an Ecological Critical Load." *Ecological Applications*, 16(2), pp. 433-439.

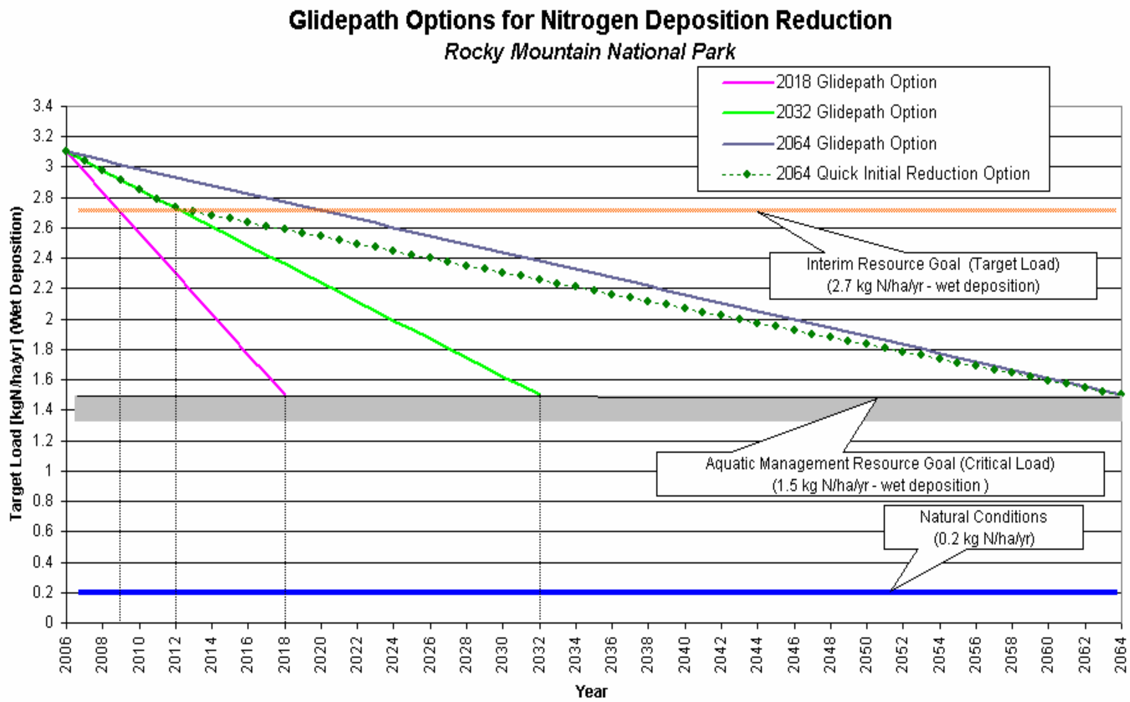


Figure IV.1.

Glidepath Option 2018, called "rapid reduction," illustrates an 11-year achievement scenario that mimics the non-attainment process, where 5 to 10 years for attaining an air quality standard is acceptable. This option was considered too aggressive and infeasible for solving an N deposition problem that took several decades to create.

Glidepath Option 2064, called "long-term," illustrates a 60-year achievement scenario that mimics the regional haze planning process, where the visibility goal is required by the year 2064. While 60 years may be appropriate for achieving an important aesthetic value, this option was considered too lengthy to adequately protect ecosystem health where sensitive resources are at risk and irreversible change is possible. The 2064 Quick Initial Reduction Option, which reaches the first "interim target load" (discussed below) by 2012 and then slows progress out to 2064, was also considered but found inadequate for similar reasons.

Glidepath Option 2032, called "moderate," illustrates a 25-year achievement scenario. This option was considered an effective time period to manage N deposition issues at RMNP under a reasonable, achievable timeframe. The RMNP Initiative Steering Committee recommends the resource management goal be achieved in 25 years, by 2032, in RMNP. The 2032 Option is presented below.

Insert figure

Figure IV.2.

D. Interim Target Loads and Progress Assessment

The glidepath approach allows for the setting of target loads for the purpose of demonstrating and assessing progress over time. An interim target load is between the current condition and the ultimate resource management goal. Current condition for RMNP is calculated as the 5-year average of wet N deposition at Loch Vale (2000-2004) which is 3.1 kg N/ha/yr.

Because ecosystems in RMNP are currently degrading, the RMNP Initiative Steering Committee recognized the importance of quickly reversing the increasing trend in N deposition. Therefore, the first interim target load, requires a reduction of wet N deposition from current conditions to 2.7 kg N/ha/yr (a 13 percent reduction from current wet N deposition) in the year 2012 (Figure 3). This target load was based on recent research and chosen to prevent the additional accumulation of N in alpine soils that may encourage the growth of grasses over alpine wildflowers.

Progress towards interim target loads will be evaluated at 5-year intervals starting in 2013 until the resource management goal is achieved in the target year 2032. These assessments will be made concurrently with the visibility improvement 5-year assessments as required by the Regional Haze Rule to optimize control strategy co-benefits in both processes. Deposition estimates for tracking progress should also be based on a 5-year average of the most recent wet N deposition data from the Loch Vale NADP site. This reduces some of the variability in the data that is due to climate.

V. Emission Reduction Options

A. NO_x Emissions

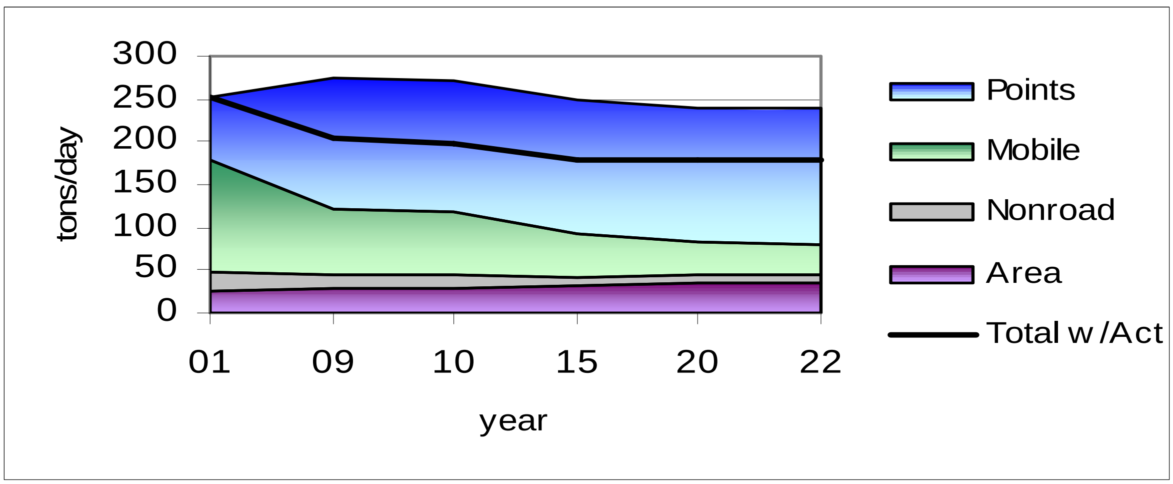
1. Benefits of Currently Planned Parallel and Related Projects

There are numerous NO_x emission control programs that have been implemented or have been scheduled to be implemented over the next 20 years. Implementation of all of these programs will reduce NO_x emissions and reduce the nitrate deposition at RMNP. Of particular note, the federal on-road vehicle TIER II standards, gasoline and diesel fuels standards, and federal off-road and small engine standards will provide significant NO_x emission reductions. The following summarizes other federal and State efforts and their benefits:

1. Ozone EAC: For the Front Range region under the Early Action Compact's 8-hour Ozone Action Plan, the CDPHE anticipates a 23% reduction in NO_x emissions by 2012, fueled by a 50% reduction from mobile sources.

2. PM10 SIP: NO_x emissions in the Denver metro area have been reduced due to the implementation of federal and State control measures. Emissions have been fairly flat since the mid-1980's, and significant reductions began to occur in 1996 due to stationary source controls and in 1999 due to mobile source controls. Under the PM10 maintenance plan for metro Denver, the CDPHE anticipates a 28% reduction in NO_x emissions by 2022, fueled by a 71% reduction from mobile sources.

Figure V-1: Denver Metro NO_x Emission Projections



*Note: the heavy black line on the graph labeled "Total w/ Act" represents actual projected emissions from point sources; the blue shading above this line represents point source emissions increased to potential to emit levels.

3. Minor Source BACT for Natural Gas Compressor Engines (greater than 100 hp): The AQCC adopted emission limits for new and relocated engines in 2006 that reduce the growth in NO_x emissions across the State. The quantity of emission reduced has not been determined as the number of new/relocated engines coming into the State is unknown.

4. Regional Haze: For western states, the regional haze program will reduce NO_x emissions from major stationary sources due to the Best Available Retrofit Technology provisions and from any other sources required to reduce emissions to demonstrate reasonable progress toward the regional haze goal. This Regional

Haze effort should reduce NO_x emissions approximately 30% by the year 2020 (included in this percentage are benefits from other existing programs, such as mobile source reductions).

5. Mobile Source NO_x Trends East of the Park: Table V-1 provides current and projected estimates of mobile source NO_x emissions for the Front Range. This data indicates that NO_x emissions will be about 68% less by 2020 and 75% less by 2030. The Fort Collins and Greeley areas are currently experiencing and are expected to experience rapid urbanization and growth. Fortunately, the federal TIER II tailpipe and fuels standards are countering this growth and significantly reducing projected emissions. It can be assumed that these future trends will also manifest themselves in the Estes Park and RMNP region, which are also experiencing dramatic mobile source activity and increases in vehicle miles traveled.

Table V-1: Mobile Source NO_x Emissions Estimates for North Front Range Areas

Year	M6 NOX EF (gr/mi)	Fort Collins VMT	Fort Collins NOx – TPD	Greeley VMT	Greeley NOx - TPD	NFR total VMT	NFR total NOx - TPD
2000	3.083	2,651,091	9.0	1,264,236	4.3	9,658,415	32.8
2010	1.578	3,179,615	5.5	1,516,855	2.6	12,003,242	20.9
2012	1.312	3,317,204	4.8	1,575,099	2.3	12,599,100	18.2
2020	0.650	3,778,538	2.7	1,851,248	1.3	14,840,487	10.6
2030	0.393	4,709,117	2.0	2,327,133	1.0	19,280,346	8.4

2. NO_x Control Options

Table V-2 provides a list of possible NO_x control options for consideration without any prioritization of which options are preferred other than organizing by source category. Some NO_x control options also provide collateral decreases in volatile organic compounds (VOCs) that may benefit ozone levels in the Park. Each option is discussed in greater detail below with some qualitative or quantitative discussion of emission reductions and estimated costs. The appendices include additional details and information on the assumptions related to most of the control options.

TABLE V-2: NO_x Control Options	
NO_x Control Options for Stationary Sources	
1	SCR on New or Existing EGU's and Boilers (See Appendix A – Table A-1: Scenario 1)
2	SNCR on New or Existing EGU's and Boilers (See Appendix A – Table A-1: Scenario 2)
3	LNB on New or Existing EGU's and Boilers (See Appendix A – Table A-1: Scenario 3)

4	ULNB on New or Existing EGU's and Boilers (See Appendix A – Table A-1: Scenario 4)
5	NSR LAER and Offsets for Major Sources Statewide (See Appendix B)
6	Controls on Non-BART Major Sources and BART-Eligible Sources not Subject to BART (See Appendix C)
7	NO_x Emissions Cap and Trade Program (See Appendix D)
8	Pollution Prevention and Voluntary Reductions (See Appendix E)
9	Alternative, Renewable, or Energy Efficiency Requirements (See Appendix F)
NO_xControl Options for Mobile Sources	
10	Local VMT Reductions (See Appendix G)
11	Adopt EPA HC/ NO_x Cutpoints into I/M Program
12	I/M to Control NO_x for Denver Metro and North Front Range
13	Dirty Screen RSD with Enhanced I/M
14	Dirty Screen RSD without I/M
15	On-Board Diagnostics
16	Address Vehicles that Never Pass I/M240 After Failing Initial Test
17	New Vehicle On-Road California LEV II Tailpipe Standards (See Appendix H)
NO_x Control Options for Area Sources	
18	Off-Road and Small Engine California Standards (See Appendix I)
19	State-wide New/Existing Engine Controls (See Appendix J)
20	Minor Source New/Existing BACT for Natural Gas Compressor Engines (greater than 100 hp)

a. NO_x Control Options for Stationary Sources

1. SCR on New or Existing EGU's and Boilers

The application of selective catalytic reduction (SCR) could reduce NO_x emissions from existing and new boilers and electrical generating units (EGU's) using best available post combustion controls. Ammonia (NH_3) is injected into the exhaust stream with a catalyst bed to enhance the reaction. The estimated reduction from installation of SCR on all existing coal-fired boilers >44 MW statewide would result in a NO_x reduction of about 58,580 tons per year at an approximate cost of $395 million dollars.

2. SNCR on New or Existing EGU's and Boilers

Selective non-catalytic reduction (SNCR) could be used where NH_3 is injected into the exhaust stream to control NO_x emissions. The estimated reduction from installation of SNCR on all existing coal-fired boilers >44 MW statewide would result in a NO_x reduction of about 39,940 tons per year at an approximate cost of $38 million dollars.

3. LNB on New or Existing EGU's and Boilers

The estimated reduction from installation of low- NO_x burners (LNB) on the few remaining coal-fired boilers without LNB (Arapahoe Unit 3 and Cherokee Unit 2) would result in a NO_x reduction of about 1,261 tons per year at an approximate cost of $284 thousand dollars. Further reductions may be possible if the latest generation of LNB were installed on other existing boilers and EGUs with older LNB technology.

4. ULNB on New or Existing EGU's and Boilers

Installation of the latest generation of ultra low- NO_x burners (ULNB) could reduce NOx emissions by 10,292 tons per year at a cost of about $3 million dollars.

5. NSR LAER and Offsets for Major Sources Statewide

For major sources in Colorado, a permitting program similar to the nonattainment new source review (NSR) program could be implemented. For new and modified sources with NO_x emissions greater than 100 tons per year, the requirements would include lowest achievable emission rate (LAER) control technology and offsets for the remaining NO_x emissions. This would help control the growth in NO_x emissions. The State has the authority to adopt such a program as long as it does not become part of the federal SIP.

The exact emission reductions are unquantifiable on future sources, however generally, Large Combustion Turbines with Combined Cycle (> 25 MW) using natural gas (includes propane & liquefied petroleum gas) can achieve – 1.5ppm to 2ppm at 15% O2. This is being achieved through the use of combined control technologies such SCR and low NO_x combustors. For Large Internal Stationary Combustion Engines (> 500 hp) using natural gas (includes propane & liquefied petroleum gas) - .0015 g/hp/hr - 1 g/hp/hr. This is being achieved through the use of clean burn technology (lean burn, non-selective catalytic reduction [NSCR]). Small Internal Stationary Combustion Engines (< 500 hp) using natural gas (includes propane & liquefied petroleum gas) - .15 g/hp/hr - 2 g/hp/hr. This is being achieved through the use of clean burn technology (lean burn, NSCR, air/fuel ratio controller).

6. Controls on Non-BART Major Sources and BART-Eligible Sources not Subject to BART

A process designed to achieve Best Available Retrofit Technology (BART) from pre-1962 major sources (similar to the BART provisions adopted in March 2006) would result in emission reductions from under- and non-controlled facilities. There are about 20 Front Range major source facilities with a variety of pre-1962 emissions units that emit about 52,660 tpy of NO_x (uncontrolled or under-controlled).

Although, each emissions unit would require a case-by-case evaluation to determine technical feasibility, if selective catalytic reduction (SCR) or non-selective catalytic reduction (NSCR) was applied on all emissions units the anticipated NO_x emissions reduction would be about 44,763 tpy (assuming an average control efficiency of 85%) at a cost ranging from $67-$179 million dollars. If low NO_x burner (LNB) technology was applied on all emissions units, the anticipated NO_x emissions reduction would be about

28,880 tpy (assuming an average control efficiency of 45%) at a cost ranging from $4-$9 million.

7. NO_x Emissions Cap and Trade Program

A geographically weighted NO_x cap and trade program is one approach available for controlling the growth in, and/or obtaining reductions of, NO_x emissions. The concept entails capping emissions at present levels and then incrementally reducing the cap to achieve the RMNP goals of improved visibility and reduced nitrification and ozone levels. All sources of nitrogen emissions should be considered for inclusion into the program and consideration given to geographically weighting emissions reduction caps based on the relative importance of source areas affecting the Park. A cap and trade program would provide Colorado sources with the flexibility to achieve NO_x reductions through controls or by purchasing allowances under the program, allowing market forces to drive the effort. This could be a State-only program, or if adopted as a major component of either the State's regional haze or ozone SIPs, although trading would then become federally enforceable.

The EPA Acid Rain Program (National) and South Coast's RECLAIM Program (Los Angeles Metro Area) are successful examples of active cap and trade programs. These are large-scale emission reduction programs that operate with a level of complexity that far exceeds any cap & trade program possible for Colorado. Point sources represent the best category of candidates for a cap & trade program since the emissions are readily tracked through the APEN permit process. The Colorado 2006 point source NO_x (4650 sources) emission inventory is estimated at 178,683 tpy. A statewide cap & trade program for NO_x sources might be viable although over 4500 sources emit less than 100 tpy. The cost of tracking and administering such a large number of small sources may require considerable resources.

8. Pollution Prevention and Voluntary Reductions

Pollution prevention, referred to as P2, refers to voluntary emission reduction measures that have potential for positively affecting air quality. Voluntary VOC and NO_x reductions from large and small sources would assist in reducing nitrogen deposition, as well as ozone, PM and visibility impairment. Voluntary measures offer a positive means for achieving environmental benefits while providing sources the flexibility of a non-regulatory program, often at a cost savings. However, the benefits and costs of voluntary reductions cannot be quantified due to the uncertainty regarding actual P2 application by the emissions-producing community.

P2 was established as a national policy under the Federal Pollution Prevention Act of 1990 and has also been established as a public policy of the State of Colorado through the Pollution Prevention Act of 1992, stating that "pollution prevention is the environmental tool of first choice." There are local and regional contacts for P2 assistance programs and resources, including from the U.S. EPA for partnership programs with industry, grants and funding to support state and tribal P2 programs, and technical assistance services offered through EPA and various state offices and partners.

The CDPHE is in the process of attempting to integrate and incorporate pollution prevention and environmental leadership program strategies into the agency's permitting, inspections, enforcement, rules development, remediation, assistance, and other functions. The CDPHE P2/environmental leadership program includes: policies, strategies, and projects designed to use flexibility and other innovations to encourage organizations to achieve results through pollution prevention, the Environmental Leadership Program and other innovations, for enhanced environmental outcomes.

Voluntary reduction measures should be included in a comprehensive control strategy to benefit air quality, but there is uncertainty about this control option's ability to improve nitrogen deposition in RMNP because of the lack of implementation details within State voluntary programs. Enhanced policy direction for Colorado's existing P2 program could potentially be more effective by encouraging voluntary NO_x and NH_3 reduction measures through incentives, directed assistance programs, and reduction targets. This additional emphasis could contribute to air quality improvements generally and provide assurance that a directed program would yield more benefits. Outside of a voluntary P2 program, the State could provide disincentives to pollute within its existing regulatory programs by charging new or increasing current emissions fees on processes or activities that result in emissions that could be avoided or reduced by employing P2 alternatives.

9. Alternative, Renewable, or Energy Efficiency Requirements

Electric power generation sector NO_x emissions growth can be offset by use of energy efficiency and renewable energy resources (e.g., wind, solar, biofuels, geothermal, and hydropower) in the near future. The Air Pollution Prevention Forum (AP2) of the Western Regional Air Partnership (WRAP), in which Colorado is a participating State, developed renewable energy and energy efficiency policy and program recommendations that would reduce emissions and electricity production costs in the western region of the U.S. These recommendations followed on the findings of the Grand Canyon Visibility Transport Commission's (GCVTC), and the WRAP has supported the GCVTC's renewable energy goal of 10% generation of electric power from renewable resources by 2005 and 20% by 2015 (known as the 10/20 goal) along with increasing the use of energy efficiency technologies in the region. Energy efficiency technologies include the continued development and implementation of national energy efficiency standards for motors, appliances and lighting, and the construction of energy efficient buildings.

An assessment conducted for the AP2 Forum by ICF Consulting reported that the emissions reduction in NOx from implementing the 10/20 goals and energy efficiency recommendations would be between 8,000 to 14,000 tons annually. In addition, the assessment found that these measures: could reduce power demand in the West by 8% by 2018; lower costs for meeting air quality regulations; offer savings in energy and costs of new fossil-fired power plants; provide for increases in affordable and reliable electricity; and offer economic development opportunities for rural areas and tribal lands.

Overall, the study found that increasing renewable generation to 20% by 2015 could reduce electricity production costs in the region by an average of $700 million per year as a conservative estimate. The annual levelized economic benefits for Colorado in 2001 dollars ranged from $258 million in gross regional product to $288 million in real disposable income.

Work products from WRAP's AP2 Forum are available to states and tribes for use in developing programs in their areas, including regional haze SIPs for reducing future impacts of NOx emissions growth related to power generation. Five states in the WRAP region that adopted section 309 regional haze SIPs already are required to include a variety of information addressing energy efficiency programs, renewable energy production and consumption, and descriptions of programs and policies each state will rely on towards meeting the GCVTC's regional goal for renewable energy. Colorado's neighboring states of Wyoming, New Mexico, Utah, and Arizona are all section 309 SIP states. Colorado could adopt similar measures as part of their regional haze SIP under section 308.

The policy, individual and corporate options included in the AP2 Forum's recommendations for this type of pollution prevention strategy should be feasible for the State of Colorado. Many of the strategy elements are already being implemented, but perhaps without a comprehensive, coordinated State policy or program in place.

b. NO_x Control Options for Mobile Sources

10. Local VMT Reductions

Similar to other areas of the State, light and heavy-duty vehicles that account for the VMT near the park are on average becoming cleaner burning with fewer emissions. However, local vehicle-miles-traveled (VMT) reductions in and near RMNP have been suggested to reduce emissions affecting the Park. Further restricting or banning vehicles in the Park and controlling/reducing VMT in the Estes Park and Northern Front Range region would reduce emissions from those close-in sources. Other methods of reducing VMT include mass transit systems, carpooling/vanpooling, and development of new or modification of existing routing to make it more efficient. With an accurate, geographically distributed VMT for the county's road traffic system, the Mobile 6 model could be used to predict the effect of local VMT reductions on air quality in the surrounding area, including RMNP.

11. Adopt EPA HC/ NO_x Cutpoints into I/M Program

The current Inspection/Maintenance (I/M240) cutpoints were originally designed to address carbon monoxide, not hydrocarbon (HC) or NO_x. As a result, there may be some additional emission reductions available by tightening the HC/ NO_x cutpoints. If the current I/M program was retooled to include the tightest EPA NO_x /HC cutpoints, the Division estimates (MOBILE6) a NO_x emission reduction of 13.2 tpd (4,818 tpy) and a HC emission reduction of 1.8 tpd (657 tpy). There would be increased repair cost to owners of failed vehicles and such costs are difficult to quantify.

12. I/M to Control NO_x for Denver Metro and North Front Range

Either a new I/M program would need to be designed or the current I/M program would need to be re-tooled and expanded to achieve NO_x reductions without increasing carbon monoxide emissions. *Doug to redo*

13. Dirty Screen RSD with Enhanced I/M

A dirty screen program would utilize current remote sensing device (RSD) equipment to identify dirty vehicles. Upon detection, the vehicle owner would be required to take the vehicle in for a confirmatory inspection. The time period of this required inspection could range from months to requiring the vehicle to be inspected at the time of its next registration. A dirty screen program would compliment the I/M program and significantly reduce the current program network. If the existing I/M program is maintained and a dirty screen program is added, emissions would likely decrease. Emission benefits difficult to quantify and field tests of the dirty screen technology indicate some problems with false positives that could lead to additional motorist inconvenience.

14. Dirty Screen RSD without I/M

A dirty screen program would utilize current RSD equipment to identify dirty vehicles. A dirty screen program without the confirmatory testing of the current I/M program has many feasibility and implementation issues that have not been developed. The program would have to utilize uniformed law enforcement officers to pull over, ticket, and require repair of smoking vehicles/vehicles suspected of being out of compliance with emissions requirements. If a dirty screen program is used in lieu of the existing I/M program, the magnitude of the emissions change is not known. Field tests of the dirty screen technology indicate some problems with false positives. The location of RSD equipment may limit identification of high emitters. A dirty screen program can be built to achieve NO_x emissions reductions, both in the Denver metropolitan area and along the Front Range.

15. On-Board Diagnostics with I/M

Model year 1996 and newer vehicles have on-board diagnostics (OBD-II) technology. A transponder could be used to select vehicles and/or fleets (post -`96 vehicles) to report OBD status. The program would be less effective than the current enhanced program. If the existing I/M program added an OBD I/M Program, applicable to ’96 and newer vehicles, the Division estimates (MOBILE6) a NO_x emission reduction of 3.5 tpd (1,278 tpy) and a HC emission reduction of 1.3 tpd (475 tpy).

If an OBD I/M program was substituted for the existing I/M program, the Division estimates (MOBILE6) a NO_x emission increase of 1.4 tpd (511 tpy) and a HC emission increase of 4.5 tpd (1643 tpy). The cost effectiveness of an OBD program is still in question and is less than an I/M 240 test but the repair costs (10 to 1 fail rate) may offset the inspection cost benefit. If coupled with dirty screening, NO_x reduction benefits can be achieved.

16. Address Vehicles that Never Pass I/M240 After Failing Initial Test

Some percentage of the vehicles that failed their initial I/M240 never passed or were issued a waiver to register the vehicle. In 2005, over 100 vehicles were granted waivers in the Denver metro area for one year. There is concern that these vehicles may continue to operate within the Denver Metro area. Identifying and repairing these vehicles would result in fewer emissions. The fate of these vehicles is unknown and there is a lack of resources to investigate and determine the status of these vehicles. The cost of repairing these vehicles, however, is typically very high because high mileage and engine wear.

17. New Vehicle On-Road California LEV II Tailpipe Standards

California has the most stringent on-road tailpipe standards for new vehicles in the nation. Other states are allowed to adopt these standards if a need is adequately demonstrated, as the states of Washington, Oregon and New York have already done. Implementation of California vehicle emission standards (CA LEV II) would take years, thus it is likely that the implementation date for the new federal standards (2009) would closely correspond with the date a California vehicle emission standard could be implemented in Colorado. After 2009, all vehicles manufactured to the federal NO_x standard must average (0.07 g/mi) over the 8-certification bins for light and medium duty passenger vehicles for 120,000 miles. Similarly, vehicles manufactured to the CA LEV II standard must meet a (0.07 g/mi) for all passenger and light-duty vehicles < 8500 GVW. Thus, from the perspective of reducing NO_x emissions, the CA LEV II standard is not an improvement over the federal emission standard. Thus the additional costs (approximately $2000 per vehicle) of the CA LEV II program may far outweigh any minimal if any NO_x reductions achieved by implementing a California vehicle emission program. The actual benefits of a CA LEV II would require MOBILE6 modeling to attempt to quantify the full extent of any NO_x emissions reduction.

c. NO_x Control Options for Area Sources

18. Off-Road and Small Engine California Standards

The implementation of the California small engine standards would result in about a 70% reduction in NO_x & HC emissions. The Division estimates that about 24% of the total summertime NO_x emissions are from lawn & garden and other off-road equipment at about 450 tpd. Assuming 70% control would result from the implementation of California Tier II standards the maximum expected NO_x reduction is about 315 tpd (summertime). Since small engine use varies by season, it is difficult to project annual emission reductions.

CO would not be permitted to incorporate into regulation California standards for spark-ignition off-road engines below 50 horsepower. However, this control option could be used as a voluntary program where manufacturers of California-compliant small engines are asked to voluntarily sell these lower emitting units in Colorado. Based on cost analysis by the California Air Resources Board (CARB), the expected increase in cost of equipment that meets CARB Tier II standards will range from $0-$35 over comparable equipment today.

19. State-wide New/Existing Engine Controls

NO_x emissions from existing reciprocating internal combustion engines (RICE) are relatively uncontrolled in Colorado due to their minor source status. The AQCC has adopted changes to Regulation 7 that would phase in NO_x emission standards of 2 gram per horsepower hour (HP-hr) in 2008 and 1 gram per horsepower hour (HP-hr) in 2011 for new and relocated into the State natural gas fired engines between 100 and 500 horsepower. The proposed standards for natural gas fired RICE > 500 HP are 2 gram per horsepower hour (HP-hr) in 2007 and 1 gram per horsepower hour (HP-hr) in 2010. Retrofit technology for existing rich burn and lean burn engines is cost effective.

An analysis found that all early action compact (EAC) area (generally North Front Range) RICE emitted about 13,000 tons per year. With rich burn retrofit controls (for EAC area), it was found that NO_x would be reduced to 44 tons/year with non-selective catalyst reduction (NSCR) and air fuel ratio controller (AFRC) controls.

For engines greater than 300 hp, the EPA estimates that the average cost of NSCR per ton of NO_x reduced is about $98/ton (for engines up to 2000 hp). The average cost of NSCR per ton of NO_x reduced on engines 100 - 300 hp is on average $153/ton. The average cost for SCR on lean burn engines greater than 300 hp is $9133/ton and for engines 100 - 300 hp is $7760/ton.

20. Minor Source New/Existing BACT for Natural Gas Compressor Engines (greater than 100 hp)

The largest and fastest growing category of NO_x emissions is minor sources that, for the most part, are uncontrolled. Significant, growing emission categories include the minor source power generation and the oil and gas exploration industries. Exploration for natural gas is increasing in Colorado and throughout the West. NO_x emissions from the oil and gas industry are increasing and are relatively uncontrolled in Colorado due to their minor source status. The surrounding States of Wyoming, Utah, and New Mexico have some degree of minor source Best Available Control Technology (BACT) requirements, and a Colorado program could be modeled after these State’s programs. NO_x controls for engines are readily available and have been adopted Statewide. Other minor sources of these emissions need to be investigated and control options developed.

B. Options to Reduce Ammonia Emissions

1. Agricultural Livestock and Crop Production

Acknowledgement

> The MOU agencies wish to recognize the important work performed by the RMNP Initiative's Agriculture Workgroup. This workgroup, primarily consisting of livestock, crop, and commercial fertilizer industry stakeholders, first convened in September 2006 and provided their report in February 2007. It is believed that this is one of the nation's first such stakeholder group convened to develop a strategy to help reduce ammonia emissions from agricultural sources. The complete results of the Agriculture Workgroup's report, including research citations and references are provided in Appendix XX of this plan. The MOU agencies used this information to present the summary that follows.

a. Introduction

The agricultural sector uses voluntary, site-specific methods, structures and practices, or best management practices (BMPs) to prevent or reduce environmental impacts to air, water or land. In the last 35 years, systems designed to manage agricultural operations have been optimized for water quality protection purposes to comply with EPA effluent limitation guidelines. In the past five years, agricultural-related regulatory discussions at the federal and state levels have begun to focus attention on air quality issues. For example, ammonia volatilization was considered a desirable means to remove nitrogen from manure to balance nitrogen for land application, and only recently has ammonia loss been viewed as a potential problem in terms of air quality considerations. As such, the capability of BMPs to reduce ammonia and the potential for unintended consequences to air, water and land that may result from implementation of a BMP, must be evaluated and understood prior to implementing BMPs as ammonia reduction control options.

BMPs to reduce ammonia emissions are viewed by the RMNP MOU agencies as appropriate for the agriculture industry. At this point in time, many potential BMPs are in research and development phases and may not be feasible for widespread implementation. Implementation of BMPs before their efficacy in reducing emissions of ammonia are quantified may lead to economic burdens on agricultural producers without corresponding reductions in nitrogen deposition in RMNP, which could make agricultural producers less receptive to implementing effective BMPs proposed in the future. To make agricultural BMPs a reality, Colorado State University is researching BMPs under development throughout the nation and is working with the Colorado's agriculture producers to establish pilot projects to test and quantify the efficacy of BMPs in reducing ammonia emissions. Once this work and other similar projects are completed, the MOU agencies will work towards broad implementation of cost-effective BMPs in Colorado.

It is anticipated that CSU and other research on BMPs will provide valuable information on viable BMPs for the agricultural sector. In the interim, agricultural producers will be encouraged to voluntarily implement BMPs that are considered to be standard industry practice, and are thought to result in reductions of ammonia emissions. The following information provides a basic overview of BMPs (see Table V-3) that are currently available for implementation (marked with an "*" by their title) or that may demonstrate a potential for reduction of gaseous ammonia emissions, allowing for either 1) wide-spread implementation over the next five years, or 2) further investigation of ammonia emissions reduction from livestock and crop production. BMPs currently in use will provide a starting point for applied on-farm research to identify ammonia reduction potential while other BMPs will be used to develop an evolving research strategy on ammonia reduction BMPs for production agriculture.

TABLE V-3: NH_3 Control Options	
NH_3 Control Options for Crop Production	
1a	Tillage: Conventional Tillage
1b	Tillage: Conservation Tillage*
2a	Fertilizer Use: Fertilizer Selection*
2b	Fertilizer Use: Fertilizer Application Rates*
2c	Fertilizer Use: Soil Acidification
2d	Fertilizer Use: Urease Inhibitors
2e	Fertilizer Placement*
3	Fertilizer Storage and Handling
NH_3 Control Options for Livestock	
1a	Nutrient Management: Reducing Dietary Crude Protein*
1b	Nutrient Management: Phase Feeding*
1c	Oscillating Protein Feeding for Ruminants
2a	Livestock Management: Genetic Selection
2b	Livestock Management: Feed Additives and Hormones
3a	Facility Design and Management: Barns*
3b	Facility Design and Management: Drylots
4a	Wastewater Management: Lagoon Acidification
4b	Wastewater Management: Lagoon Aeration
4c	Wastewater Management: Stratified Lagoons
4d	Wastewater Management: Lagoon Covers
4e	Wastewater Management: Effluent Use
4f	Wastewater Management: Wastewater Runoff
5	Manure Storage
6	Land Application of Manure*
7	Pasture Management*

b. BMPs for Crop Production

Crops can either be a sink for gaseous ammonia by plant uptake through leaves or deposition on leaf surfaces, or an ammonia source through leaf volatilization or plant residue decomposition. Volatilization of ammonia can occur during all stages of crop production including tillage, fertility management, and plant cutout. Volatilization of ammonia may also occur at the end of the growing season when plant tissue dries, possibly due to chlorophyll degradation.

Due to the spatial variability within the plant where these processes occur and to variability in atmospheric and soil ammonia concentrations, ammonia volatilization from cropping systems is difficult to predict. However, several management practices have been suggested which have the potential to reduce overall nitrogen volatilization from crop production in Colorado and therefore impact the level of nitrogen deposition in RMNP. Some potential control options for limiting ammonia volatilization from crop production are as follows:

1. **Tillage**

   a. **Conventional Tillage**

Ammonia emissions from cultivated systems without fertilizer additions from manure or synthetic sources are low. Therefore, there are no BMPs for ammonia emissions from tillage effects alone. Effects of fertilizer addition will be discussed below.

   b. **Conservation Tillage***

Conservation tillage is a practice whereby crop residues are left on the soil surface from year to year rather than deep plowing the soil every year. Conservation tillage may be practiced in varying degrees: from no-till systems where all crop residues are left on the surface and subsequent crops are planted directly into the stubble, to strip-till systems where strips of land are tilled for seed and fertilizer placement while leaving crop residue between seedbeds. Additional research needs to be conducted to determine if long-term conservation tillage practices reduce overall nitrogen requirements of cropping systems used in Colorado, especially when land application practices of animal waste products and commercial fertilizers are broadcast on fields where conservation tillage is being practiced.

2. **Fertilizer Use**

   a. **Fertilizer Selection***

An effective BMP for reducing ammonia volatilization from crop production in Colorado is to choose the nitrogen fertilizer most appropriate for a given cropping system that will have the lowest nitrogen volatilization on the soil type to which it is being applied. Fertilizers with non-precipitating anions, such as ammonium nitrate or ammonium chloride, should be used on calcareous soils (which prevail in eastern Colorado) to maximize nitrogen availability to the plants, thus reducing the amount of nitrogen available for volatilization.

In many cases, producers are practicing agronomic application and “soil–appropriate” fertilizer choices. Many farmers in eastern Colorado use anhydrous ammonia, which typically has lower nitrogen losses on high pH soils. In the Front Range counties closest to RMNP, ammonia is rarely used and is not available at most farmers' cooperatives any longer due to its high volatilization rate in calcareous soils. Urea, which is the most widely used fertilizer in the world, is now infrequently used because nitrogen losses are extremely high when applied to eastern Colorado’s calcareous soils. The use of soil appropriate fertilizers should be widely promoted in Colorado.

Selection of controlled release fertilizers may also reduce ammonia volatilization as nitrogen is made available to the plant over a longer period of time. If managed well, this practice may increase nitrogen utilization by the plant, thus reducing ammonia volatilization by decreasing the nitrogen gradient between the soil surface and the atmosphere. Controlled release fertilizers, however, are more expensive and may not be feasible in all production systems.

b. Fertilizer Application Rates*

Inducing higher levels of soil nitrogen than needed through over fertilization will result in greater ammonia volatilization. Fertilizer application rates should be determined based upon soil analyses (from soil samples taken throughout the root zone) as well as water analyses (in irrigated systems) and reasonable yield goals. Once yield goals have been established and soil tests conducted, necessary fertilizer application rates can be determined through consultation with a crop consultant or use of various publications. By basing fertilizer application rates on these factors, excess nitrogen usage can be avoided, thus reducing ammonia volatilization from over fertilization and increasing profitability through reduced fertilizer purchases.

c. Soil Acidification

Ammonia volatilization may be reduced by soil acidification through use of soil amendments such as sulfur compounds in crop production on calcareous soils. In many production systems, lower soil pH is desirable to promote nutrient availability as well, and many producers in eastern Colorado already apply sulfur compounds to their soils such as ammonium-sulfate (21-0-0-24 is most commonly used on grasslands), sulfur-nitrate fertilizer, or elemental sulfur. Care must be taken when employing this practice because over acidification can lead to problems such as aluminum toxicity. Additional research is needed to quantify the reduction in ammonia emissions achieved by soil acidification.

d. Urease Inhibitors

Ammonia volatilization occurs as urea nitrogen is hydrolyzed by the urease enzyme (found naturally in soils and animal feces) to form ammonia gas. Urease inhibitors slow the rate of or inhibit this reaction, thus slowing the rate of ammonia volatilization allowing the nitrogen to be retained in soils or used by plants. Use of urease inhibitors may reduce the amount of ammonia volatilized from cropping systems, especially those using urea fertilizer or animal waste, though this may be economically infeasible in many production systems due to the limited duration of urease inhibitor efficacy.

e. Fertilizer Placement*

Incorporating fertilizer or manure as soon as possible into the soil will greatly reduce ammonia volatilization, minimize the loss of ammonia, and make more applied nitrogen available for plants. Planting and fertilizing equipment that will band fertilizer with or near seeds during and after planting, are commercially available, though they often represent a significant capital investment for producers. Most producers on the Front Range are already banding their fertilizer, placing it directly into the root zone of the plants where possible. Typical subsurface banding applications during the planting operation commonly use techniques that place fertilizer within close proximity to the seed. In addition, the use of subsurface drip irrigation systems is growing in the state with an estimated 2000-3000 acres of drip-irrigation is already installed on the Front Range.

3. Fertilizer Storage and Handling*

Properly storing and managing commercial fertilizer can help to minimize emissions of ammonia from leaks, spills or other problems. Valves on fertilizer storage and application equipment should be regularly inspected for leaks and should be locked and secured when not in use. Storage tanks should also be regularly inspected for leaks or spills. In response to these concerns, a state statute and implementing regulations were adopted to protect groundwater from contamination by commercial fertilizers and pesticides at storage facilities, and fertilizer mixing and storage areas. In addition, properly calibrated fertilizer equipment and technological advances can also result in accurate application monitoring and better crop utilization with fewer emissions from over application or mechanical problems.

Due to the nature of many nitrogen fertilizers, extreme caution should be taken when developing BMPs for fertilizer storage and handling to account for the safety of those handling or in the vicinity of nitrogen fertilizer storage areas.

B. BMPs for Livestock Production

1. Nutrient Management

a. Reducing Dietary Crude Protein*

Excess nitrogen fed to animals is excreted in the waste and readily volatilized as ammonia. Through various management techniques, this excretion amount can be reduced, but the theoretical maximum possible efficiency is 50% nitrogen retention. Beef cattle, swine and poultry all experience similar inefficiencies in nitrogen utilization. Swine and poultry may excrete 60% of the total nitrogen consumed, and beef cattle can excrete as much as 80%. Matching an animal’s nitrogen intake to its production needs is critical in reducing nitrogen excretion.

Decreasing protein intake will decrease the amount of ammonia volatilized from the manure, and retain more nitrogen in the feces. Reducing the amount of ammonia volatilized from manure can have beneficial effects later in the system when manure is applied to crops by improving the nitrogen: phosphorous ratio. Most commercial cattle feeding companies hire nutritionists to monitor cattle performance and ensure that cattle diets are formulated to maximize efficiency and minimize waste. In addition, feedyards co-locate a feedmill onsite that is able to mix feed to narrow tolerances to maximize accuracy and precision, and minimize waste and costs.

Altering dietary crude protein to achieve maximum efficiency is a viable BMP that would easily gain acceptance with livestock producers because of its profitability. Continued research should be conducted to further improve the nitrogen utilization of different animal species, and the results of such research should be widely disseminated through the animal feeding industry. It should be noted, however, that matching dietary crude protein levels to animal requirements is already widely practiced by producers and that implementing BMPs to further reduce dietary crude protein in animal feeding operations may have detrimental effects because animals would utilize the nitrogen in their diets less effectively, requiring more time on feed and therefore emitting more nitrogen over their life cycle.

b. Phase Feeding*

Phase feeding is a practice whereby animals are separated by age, sex, and/or stage of growth or production. Animals have different nutrient requirements at each stage of production, and therefore different levels of dietary crude protein are appropriate at each stage. Phase feeding allows more precise matching of dietary crude protein to animal requirements by distinguishing between animals at different production stages. For the reasons mentioned above, matching of dietary crude protein to an animal's specific nutrient requirements is desirable to achieve minimum overall nitrogen excretion. Since most of the nitrogen excreted is in a form that is easily volatilized as ammonia, any reduction in nitrogen will decrease subsequent ammonia production. Therefore, phase feeding has been proposed as a BMP for reducing nitrogen volatilization from animal feeding operations and is encouraged by cooperative extension specialists for its benefits to management ease and labor utilization.

c. Oscillating Protein Feeding for Ruminants

Oscillating protein works by changing the animal's protein intake from a low to a high level every two days. The oscillating protein diet is a new method of feeding and needs further research, but the potential benefits in reducing ammonia appear promising. Before protein oscillation for ruminants is considered as a BMP, extensive research should be conducted on any specie for which this management practice is being considered.

2. Livestock Management

a. Genetic Selection

Nutrient utilization efficiency is largely dependent on genetic traits that can be enhanced by careful genetic selection. Swine and poultry producers in the United States have significantly narrowed the genetic pool of these species in the past several decades, making further gains in nutrient utilization more difficult. However, cow/calf producers still have many options available for improving nutrient utilization through selective breeding. Genetic selection may increase feed conversion efficiency and therefore reduce nitrogen volatilization in the long run. This option requires additional feasibility research to determine its wide spread viability.

b. Feed Additives and Hormones

Use of feed additive and supplemental hormones in animal production has proven to greatly improve nutrient utilization, resulting in more efficient milk and meat production. Use of such products may decrease nitrogen excretion per day and/or reduce the total number of days on feed, thereby reducing overall nitrogen excretion and subsequent ammonia volatilization. Further research should be conducted to determine the efficacy of various feed additives and/or hormones on nitrogen excretion by animal species produced in Colorado. If pursued as a BMP, special consideration should be given to account for public health, public preference, and environmental concerns associated with use of such products in animal production.

3. Facility Design and Management

a. Barns*

In dairy barns and enclosed swine and poultry barns, ammonia volatilization occurs soon after manure is deposited on the barn floor. The urea in urine mixes with the urease enzyme in feces and rapidly hydrolyzes to form ammonia gas. Each of these factors can be controlled to some degree in enclosed housing and barns.

The use of BMPs such as scraping and flushing the floors and alleyways, modifying surface floors to reduce the mixing of feces and urine: the use of lower emitting bedding materials, treatments of floors, bedding materials and litters; drying manure and cooling barn temperatures; and installing filters/scrubbers on air exchange systems all have potential to reduce ammonia emissions, but must be weighed with other potential environmental impacts. It is recommended that a holistic analysis of ammonia emissions from the entire manure management system should be thoroughly researched to determine if decreased nitrogen loss through ammonia volatilization during this stage of management leads to increased emissions in subsequent stages such as manure storage or land application.

b. Drylots

Substantial amounts of ammonia are emitted from the surface of dry lots in beef cattle feedyards and open lot dairies. Volatile ammonia emission from dry lots can be up to 70% of the total nitrogen excreted. Increasing the frequency of pen scraping can reduce ammonia volatilization from the dry lot surface. However, additional research is needed to determine whether emissions from storage and disposal of pen scrapings are affected by the frequency of manure harvest. A variety of surface amendments to reduce soil pH have been tested (with some success) on feedlot and dairy pen surfaces to assess the ability of amendments to decrease ammonia emissions. Field testing shows less success as surface amendments lose effectiveness over a short period of time and showing variable results. This is probably due to reapplication of manure on treated pen surfaces and animal hoof action breaking and removing the pen surface crust. Enzymatic treatments can be used to inhibit the hydrolysis of urine urea to ammonia by the urease enzyme in feces. An efficient, lasting, and cost effective surface amendment to reduce ammonia emissions still needs to be found. When considering these BMPs, controlling volatilization on the pen surface does not necessarily mean that volatilization is eliminated. BMPs must look at the nitrogen cycle and manure management holistically, focusing on strategies that will reduce overall emissions rather than shift the problem to another stage of the system.

4. Wastewater Management

a. Lagoon Acidification

If the pH of the lagoon is maintained above 8 (basic), ammonia volatilization increases and may be up to 70% of the total nitrogen entering the lagoon. At a pH below 6 (acidic), ammonia is bound in solution in its ionic ammonium form and little ammonia volatilization will occur. Achieving a low pH requires the addition of acidifying compounds such as alum, citric acid, or nitric acid to the lagoon. Positive results have been found in reducing ammonia emissions from small-scale waste confinement and laboratory studies, but large-scale studies are limited due to cost and feasibility of the method on production-scale livestock operations. In addition, low pH reduces the efficacy of anaerobic lagoons and may increase odor; acidic lagoon water can be detrimental when applied to crops. Additional research should be conducted to determine the minimum pH of wastewater in order to better apply wastewater to various crops cultivated in Colorado without inducing plant stress or damaging plant tissues while keeping in mind the cost, safety hazards, and possible environmental impacts associated with such practices.

b. Lagoon Aeration

Most animal waste lagoons are anaerobic in nature, and therefore most nitrogen entering the lagoon is lost as volatilized ammonia or nitrous oxide due to nitrification and denitrification processes. Aeration of lagoons may reduce nitrogen volatilization by promoting oxidation, which converts ammonia to nitrate. Even the intermittent use of aerators in swine lagoons has been shown to reduce total nitrogen and odor. However, aeration has been shown to increase ammonia emissions from aerobic lagoons under some conditions. More research will be needed to determine the conditions under which aeration reduces gaseous nitrogen volatilization before it can be effectively employed in Colorado to reduce ammonia emissions from livestock operations.

c. Stratified Lagoons

Ammonia volatilization may be reduced by use of a facultative or stratified lagoon, which has an aerobic top layer to reduce ammonia and odor emissions and an anaerobic bottom layer to promote microbial breakdown (treatment) of solids and nutrients. Stratification is achieved by mechanical circulation/aeration of the top layers of the lagoon or can occur naturally in swine lagoons where solids are low. A similar process occurs in secondary lagoons or overflow lagoons with low solids content and nutrient load. Formation of a stratified lagoon requires proper management, and more research needs to be conducted to quantify the efficacy of lagoon stratification for abatement of gaseous nitrogen loss.

d. Lagoon Covers

The addition of a lagoon cover can reduce uncontrollable variables and reduce unwanted emissions. When working properly, any of these covers can reduce nitrogen losses by 80-90%, but any cracks in the cover will greatly reduce this efficiency. When considering the use of lagoon covers as a BMP to reduce ammonia volatilization, the economic impact and feasibility of retrofitting existing lagoons should be taken into account.

e. Effluent Use

When lagoon effluent is used as flush water for barns, the remaining nitrogen retained in the lagoon water is returned to the barns and usually volatilized as ammonia. Thus, with a recycling system, the nitrogen loss potential is near 100%. If the lagoon water is used for irrigation, this volatilization potential is less (about 50%) due to nitrogen application to fields and uptake by plants. While reducing the amount of lagoon effluent may reduce gaseous ammonia volatilization, it will increase the amount of fresh water use at animal feeding operations and increase nitrogen loading to surface waters.

f. Wastewater Runoff

Little, if any, research has been done to characterize ammonia emissions from wastewater runoff control structures. Therefore, there is currently no baseline against which to measure the efficacy of any management practices intended to reduce emissions from these structures.

5. Manure Storage

Retention time of manure scraped from animal feeding facilities, until it is disposed of, varies from facility to facility. Few ideas have been proposed to reduce volatilization of ammonia from dry manure storage piles. Amendments such as alum have been proposed for reducing ammonia from poultry manure piles prior to incorporation or surface application. Research is needed for manure storages piles for species of animals produced in Colorado. Covering storage piles to reduce ammonia emissions should be researched.

6. Land Application of Manure*

Manure and/or effluent from animal feeding operations are most often disposed of by land application. Nutrient rich manures and effluents provide a valuable source of essential nutrients to cropping systems and over time can increase soil organic matter. However, significant gaseous nitrogen emissions can result from land application of manure, especially if application is not managed carefully.

Application of manure during cool weather will decrease the amount of ammonia volatilized from the manure. Precipitation also decreases the rate of ammonia volatilization by binding ammonia in the aqueous phase and moving it into the soil. Since manure is land applied under limited conditions (typically after harvests), it may be difficult to land apply during favorable meteorological conditions. For slurry, pretreatment before application may reduce ammonia emissions after the slurry is applied. More research is needed to evaluate the net environmental benefit, as emissions may occur during treatment.

Reducing manure pH is another method for reducing ammonia volatilization. Over application of acidified manure to soils, however, may decrease the soil pH, so implementation must be cautious.

Generally, manure and/or effluent is applied to soils by overhead irrigation, broadcast spreading, band spreading, trail hose, or injection. BMPs for reducing ammonia volatilization during liquid application of slurry or solids spreading should be documented. Incorporation of manure and/or effluent soon after application to land where crops are not already established may also reduce interaction between applied wastes and the air, thus reducing ammonia volatilization. Due to the volatile nature of ammonia, incorporation of slurry into the soil immediately after application is an effective means to reduce ammonia emissions, and the deeper the incorporation, the less the emissions. Slurry injection is effective for reducing nitrogen loss both during and after application, and it was found that slurry applied by shallow injection and deep injection both demonstrated low ammonia losses, but deep injection may cause root damage in grassland or established crops. Care must be taken when recommending BMPs for land application of manure and/or effluent because specific regulations are already in place to guide the land application of manure and effluent at both the state and national levels. Additional recommendations must mesh with those currently in place.

7. **Pasture Management***

The majority of ammonia losses on pasture are from urine while emissions from feces are much less. Avoiding overgrazing with proper pasture management will help reduce the amount of ammonia emitted from urine spots by increasing plant cover and nitrogen uptake. Soil conditions will also influence ammonia volatilization with greater rates of emission occurring during dry, hot weather.

2. Domestic Area Sources of Ammonia Emissions

Any comprehensive strategy developed to address nitrogen deposition in RMNP should include consideration of all potential sources of ammonia emissions including nitrogen applications in urban environments such as lawn and turf applications to parks, golf courses, recreational fields and open spaces. Any reasonable discussion of potential nitrogen volatilization sources should be contemplated in recognition of major trends impacting agriculture and urban users of nitrogen fertilizers. For example, over the period of the RMNP study, ammonia use for agricultural production has likely decreased, while urban development, corresponding water treatment volatilizations, and acres of turf requiring fertilization maintenance have increased.

It is estimated that one-quarter to one-third of urban areas are in turf as lawns, open spaces, parks, and golf courses. These areas are managed as areas that beautify home, neighborhoods, or in the larger picture, the entire city. Lawns, parks, and golf courses consume large amounts of water as well as require significant amounts of fertilizer to help them stay a lush green. Volatilization of ammonia from urban nitrogen use fertilizer use and re-treatment of run-off wastewater should be included in any comprehensive approach to managing ammonia emissions and its subsequent deposition in sensitive areas such as RMNP.

It is worth noting that the primary nitrogen compound used in the commercial lawn care industry today is urea, one of the most volatile forms of nitrogen fertilizer. Urea is favored due to characteristics that minimize “burn” or grass leaf browning when applied. Application practices often do not consider nitrogen volatilization of urea into the atmosphere. For example, commercially applied urea is not necessarily applied in a manner that allows for timely water management to minimize volatilization, such as being applied on designated “watering days” or immediately before a watering.

The MOU agencies will work to inventory the fertilizers used and the rates of application in order to estimate nitrogen emissions from urban fertilizer use. The agencies will also develop BMPs to reduce these emissions over the next 5-year period.

3. Point Sources of Ammonia Emissions

The 2006 Colorado point source ammonia emission inventory is estimated at 817 tons per year (<1% of anthropogenic sources) from 94 sources (such as power plants, wastewater treatment plants and others). Stationary sources are not obligated to report ammonia emissions, thus it is likely that ammonia emissions are under-estimated.

The top 10 sources emit 84% of the point source ammonia emissions Statewide. Several of these sources emit ammonia as a consequence of controlling nitrogen oxide emissions from combustion turbine generators (CTG) with the use of selective catalytic reduction (SCR). Two of the top 10 sources are water treatment plants with ammonia emissions of 261 tons per year. Changing the water treatment process by retrofitting or installing covers may significantly reduce ammonia emissions from these sources by up to 90%. The cost of installing covers over water treatment facilities is difficult to determine since it is site specific. Also, the recent changes to Colorado's surface water quality standards may require treatment facilities on warm water segments to reduce ammonia concentrations by volatilizing ammonia from the wastewater discharge .

The MOU agencies will work to improve emission inventory estimates for point sources in order to better estimate nitrogen emissions. The agencies will also develop BMPs and possibly regulatory requirements to reduce these emissions over the next 5-year period.

C. Cost/Benefit Discussion

Several NO_x and NH3 emission control options were evaluated for potential emissions reductions and associated costs. Table V-2 contains the list of #1-20 control options for NO_x for point, mobile and area sources. Each control option is briefly summarized and additional detailed information is included in the appendices. There are technical and resource limitations that preclude quantifying all control measures into a cost per ton of pollutant reduced. Thus, a direct comparison of dollar cost per ton across all control measures isn't possible. Table V-3 contains the list of #25-41 control options for NH3 from agriculture.

There are many other economic costs and benefits associated with air pollution. In addition to actual costs of controls, the U.S. Environmental Protection Agency (EPA) routinely calculates or discusses economic values for several effects of air quality changes (benefits for improving air quality; costs for degrading air quality):

- Human Health (mortality and morbidity)
- Visibility (use and non-use/existence[6])
- Ecological benefits (market/products, recreation, ecosystem services[7], non-use/ existence)

[6] "Non-use" or "existence" values refer to the values people place on amenities that they will not necessarily ever use, but value their existence, or value their existence for future generations.

[7] Ecosystem services, the benefits to human societies that are supplied by natural ecosystems, are essential to human societies. We depend on them to produce goods such as fuelwood, clean water and habitat for plants and animals. These services are essential to protect people from harmful ultraviolet radiation, detoxify and decompose wastes, generate and preserve soils, contribute to climate stability and maintain

- Materials damage (cleaning, repairing or replacing man-made materials)

While the EPA routinely calculates these benefits for regulatory actions, many states, including Colorado, do not have the resources to develop these estimations. To illustrate the magnitude of these benefits, however, EPA Region 8 staff estimated economic benefits of the application of "presumptive BART" sulfur dioxide and NO_x emission controls on Colorado sources.[8] Using an EPA model,[9] total health benefits in Colorado from these reductions were estimated at $49.3 million and visibility benefits were estimated at $12.7 million annually. No other benefits categories were estimated. Control costs were estimated at $12.3 million annually.

Air pollution can have an impact on tourism dollars as well. In surveys conducted at 30 national parks over a 10-year period, 89% of visitors said clean air (air quality, scenic views and visibility distance) was very or extremely important in the parks. Other studies have linked impaired air quality to less visitor time spent in a park. There are no known studies in the Rocky Mountain region estimating economic effects on tourism from air pollution. However, economic benefits from the Park as a whole can be calculated. Approximately 2.8 million RMNP visitors in 2005 spent an estimated $189 million in the local economies, which supported $103.5 million in value added (personal income, profits, rents and indirect business taxes).[10]

One study concluded that RMNP generates $8.4 in value to the public for every tax dollar invested (see Figure XX, *Benefit to Cost Ratio*).[11] That study, which was undertaken for the National Parks Conservation Association, estimated recreational benefits people derive from the park to represent economic benefits. Other values such as ecosystem services, education and science were not estimated, and thus the authors state the reported economic benefits are conservative. Economic impacts measure visitor spending and its effects on sales, personal income, jobs and value added (contribution to gross regional/local product). Finally, economic growth refers to trends due to economic activity associated with proximity to the park.

While the direct economic harm from degraded ecosystems cannot be calculated, it is clear that RMNP as a whole is a tremendous economic asset to the State of Colorado.

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biodiversity. Ecosystem services can be impaired by air pollution, at a large cost and for an extended period of time. There are many efforts to determine how to estimate the monetary value of ecosystem services, but few available studies. See, e.g.: http://www.esa.org/science/Issues/FileEnglish/issue2.pdf. (Ecological Society of America); http://www.rff.org/rff/News/Features/What-are-Ecosystem-Services.cfm (Resources for the Future). Also see this Forest Service website: http://www.fs.fed.us/ecosystemservices/

[8] Latimer, D. (2006). *Economic Benefits of Colorado BART Controls*. Presentation to Colorado Air Quality Control Commission (??), Feb. 8, 2006.
[9] Co-Benefits Risk Assessment (COBRA).
[10] Stynes, D.J. (2006). *National Park Spending and Payroll Impacts: Fiscal Year 2005*. National Park Service Social Science Program and University of Michigan, Dept. of Community, Agriculture, Recreation and Resource Studies.
[11] Hardner, J. & B. McKenney (Hardner & Gullison Associates, LLC), 2006. *The U.S. National Park System: An Economic Asset at Risk*. Prepared for National Parks Conservation Association.

Rocky Mountain National Park – Overview of Economic Importance

Economic Benefits (2004)	*Visitation*	*Total Recreational Benefits ($mil)*	*Other Benefits*[1]	*Annual Budget ($mil)*	*Benefit to Cost Ratio*[1]	
	2,781,899	$132.6	Not quantified	$15.8	>8.4 to 1	
Economic Impacts (2004)	*Visitor Spending ($mil)*	*Sales ($mil)*	*Personal Income ($mil)*	*Jobs*	*Value Added ($mil)*	
	$193.6	$209.3	$71.1	5,178	$112.6	
Economic Growth	*Annual Population Growth 1970-2003*	*Annual Employment Growth 1970-2003*	*Annual Personal Income Growth 1970-2003*	*Median Earnings per Job 2003*	*Housing Affordability: Index and Affordability Trend 1990-2000*[3]	
	(%)	*(%)*	*(%)*	*($'000)*	*1990-2000*	*Trend*
Local	3.3	4.9	5.6	$37.0	130 to 121	Less
State	2.2	3.2	4.0	$43.6	129 to 119	Less
Difference	1.1	1.7	1.6	-$6.7		Same

[1] Other park benefits not quantified include ecosystem services, biodiversity, science, education, cultural, spiritual, and passive use values. The benefit-cost ratio is conservative; it only reflects recreational benefits.

Figure XX. Source: National Parks Conservation Association

D. Air Quality Framework: Regulatory v. Voluntary Approaches

Emission reduction options can be evaluated and implemented under two paradigms: mandatory regulations, which range from command and control to incentive-based programs, or voluntary means such as pollution prevention and best management practices.

Regulation-based controls traditionally have been sought to ensure emission reductions under an enforceable legal framework. The AQCC has authority under general and specific provisions of the Colorado Revised Statutes to adopt regulations that reduce emissions. Assuming that emission reductions are necessary and forthcoming, industry benefits because there are consistent requirements under which to operate. If the regulations are determined to not be mandated by the federal government or necessary to comply with federal requirements, regulations are typically adopted as “State-only” provisions. Significant effort is expended by the CDPHE Air Pollution Control Division (APCD) and interested parties during the regulation development and public hearing processes to reach as much consensus as possible, but the AQCC has ultimate authority to promulgate regulations.

It is anticipated that some of the control options that reduce N deposition at RMNP will be adopted as regulations, especially if needed emission reductions are not or cannot be achieved through voluntary mechanisms. It is likely that some mandatory measures that reduce NO_x emissions will be recommended as part of the State’s Regional Haze (RH) plan under development for presentation to the AQCC in August 2007. The RH plan must include enforceable (i.e., mandatory) measures that improve visibility at RMNP. As stated in the MOU, signatories are committed to bring NO_x control strategies to the

AQCC that benefit RMNP. Also, some controls that begin as voluntary measures may become mandatory if consistency or equity issues arise.

Section 102 of the Colorado Air Pollution Control Act (Act), § 25-7-101, C.R.S., identifies as one of the purposes of the Act to "facilitate the enjoyment and use of the scenic and natural resources of the State." RMNP is among the "scenic and natural resources" the State. Additionally, broad authority is given to the AQCC in sections 106 and 109 of the Act, §§ 25-7-106, 108, C.R.S., to regulate any "air pollutant" and gives the AQCC "maximum flexibility in developing an effective air quality control program and [the AQCC] may promulgate such combination of regulations as may be necessary or desirable to carry out that program" consistent with section 102.

"Air pollutant" is defined in section 103 (1.5) of the Act as including "any fume, smoke, particulate matter, vapor, or gas or any combination thereof which is emitted into or otherwise enters to the atmosphere." "Nitrous oxide" meets this definition and is expressly regulated as one of the 6 ambient air quality pollutants necessary for a SIP. See section 109(2)(c), § 25-7-109(2)(c), C.R.S. However, nothing in the Act precludes the AQCC from regulating nitrous oxide for other purposes than compliance with section 110 of the Clean Air Act, such as for "air quality related values (AQRV)" (see sections 1001-08 of the Act) in RMNP, as long as the source or category of sources is determined to be emitted in significant quantities under section 109 of the Act.

Sections 1001-1008 of the Act, § § 25-7-1001 to 1008, C.R.S. establishes a protocol for the AQCC to promulgate regulations for Class I areas related to AQRV's that have been adversely impacted by air pollutants. However, the AQCC is not limited to utilizing this procedure, but can go through its normal rulemaking procedures as established in the Procedural Rules of the AQCC.

Voluntary emission reductions, which will be important for improving conditions at RMNP, frees sources to achieve the desired reduction in a means solely determined by the source. Rather than being enforceable, this approach requires sincere commitments by sources to implement voluntary emission reduction measures on an ongoing basis. Some voluntary measures could prove to be cost effective if efficiencies are gained or if the measures stave off mandatory measures that may be more costly. Assuming that some sources voluntarily reduce emissions and some do not, a competitive advantage may result, favoring the source that did not invest resources to achieve the reductions; mandatory measures may then need to be implemented. Incentives can help to defray the costs and difficulties of voluntary control. These incentives could be streamlined permitting, tax breaks or credits, positive public relations, recognition by the State and trade associations, etc. A number of potential emission control options, including reducing agricultural emissions of NH_3, may be effective on a voluntary basis.

During the Initiative process, questions have arisen regarding the state's authority to regulate sources of NH_3. Ammonia is a pollutant as defined in section 109 of the Colorado Air Pollution Prevention and Control Act ("Act"), § 25-7-109(2)(c), C.R.S. because it is a "chemical substance," one of the categories in the definition of "pollutant" in that section. Therefore, as an air pollutant, it can be regulated by the Commission as provided in § 25-7-109(1)(a) if it is being emitted from a “significant source” or “category of sources” or from “each type of facility, process, or activity which produces or might produce significant emissions of [ammonia].” *Id.*

There is an exception from such regulation for certain types of facilities, sources, or categories of sources of ammonia emissions; specifically “agricultural, horticultural or floricultural production” such as “farming” and “animal feeding operations.” *See* § 25-7-109(8)(a), C.R.S. However, there is an exception to this exception; that is, the following facilities or sources of ammonia emissions are subject to reasonable regulation by the Commission even though they would otherwise fit into the above exceptions. These facilities or sources are “swine feeding operations as defined in section 25-8-501.1(2)(b).” Other exceptions to the exceptions are “ ‘major stationary sources’ as defined in 42 U.S.C. sec. 75602(j), sources required to be regulated by Part C (prevention of significant deterioration), Part D (nonattainment) or Title V (minimum elements of a permit program)”, or which are participating in the “early reduction program of section 112 of the federal [Clean Air Act]. *Id.*

Based on the above, and on technical documents and studies which identify certain types of operations as contributing to ammonia emissions which eventually become deposited in the Park, the following types of stationary facilities or operations are examples of facilities or operations that conceivably would be subject to regulation by the Commission: coal fired utility power plants, oil and gas refineries, cement plants, municipal sewage facilities, swine feeding operations, and any animal feeding or other farm operations that could be classified as major stationary sources (100 tons per year of ammonia emitted). *See* 42 U.S.C. 7602(j)). Conceivably this last category could include commercial turkey, chicken, or dairy or cattle operations if the particular source fits the definition of stationary source, it emits ammonia in a manner that can be measured, and such measurements exceed 100 tons per year.[12]

E. Water Quality Framework: Cross-Media Opportunities and Options

While most of the efforts to reduce N emissions are occurring through air quality programs, there are several actions that can be taken under the auspices of water quality programs that may complement these other activities. The Water Team has identified three potential paths that could be pursued alone, simultaneously, or at different times. One approach uses the Clean Water Act regulatory authorities and the other is to enhance the existing collaborative, multi-media effort using elements of Clean Water Act authorities, as well as a variety of other authorities and activities.

1. Background

[12] Non-stationary sources, to the extent they can be shown to emit significant amounts of ammonia and/or which the Commission determines contributes to air quality related impairment in the Park, could also be regulated. *See* discussion in text, *infra* and §§ 25-7-1006 through1008, C.R.S.

Lake sediment cores on the east side of RMNP show that the species shifted from a natural oligotrophic (low nutrient) state to a eutrophic (high nutrient) state in the 1950s, prior to the designation of park waters as “outstanding waters” in 1981 (discussed below.) While published research shows that these biological changes are related to N deposition, actual monitoring of water chemistry in the park did not occur until the mid-1980s, several decades after nitrate concentrations became elevated. Monitoring of surface water nitrate in the Park between the mid-1980s and the present does not clearly show any additional increases in nitrate, just a continued elevated condition. The relationship between nitrogen deposition and surface water nitrate is complex, because N is chemically and biologically processed in soils and vegetation, before it enters surface waters (relatively small amounts of N enter the surface water directly compared to the area of the watershed which ultimately empties into the surface water). In general, increasing nitrogen deposition over time causes nitrogen in soils and plants to increase until a “nitrogen saturation” threshold is exceeded. When this occurs, nitrogen leaches (and chemically transforms into nitrate) into the water body and nitrate in surface waters goes from zero or near zero (“stage 0” nitrogen saturation) to occasional spikes above zero (“stage 1”) to consistently elevated above zero (“stage 2”). Because nitrogen progresses through several components of the ecosystem, nitrogen saturation stages are applied to the ecosystem as a whole. The Loch Vale watershed currently has consistently elevated nitrate, so is considered to be in “stage 2’ nitrogen saturation (out of 4 possible stages: 0-3).

Monitoring of lakes and streams in RMNP was not conducted prior to the time that the nitrogen saturation threshold was exceeded, so it is not known when this condition first occurred, only that nitrate was already elevated when monitoring began in the mid-1980s.

Saturation releases would not be the only source of nitrogen to the waters. Nitrogen releases to streams may be cyclic and sporadic and not always dependent upon exceeding a threshold in soils and plants from nitrogen deposition. Leaf fall, photosynthesis, respiration, and overland flow all influence chemical and biological reaction rates and the physical transport of nutrients from a watershed.

2. Clean Water Act Authorities to Restore Water Quality

The Clean Water Act provides some opportunities to obtain through rulemaking recognition of water quality degradation and for listing the water bodies as impaired. The Section 303(d) list is produced by the Water Quality Control Commission (WQCC) every even-numbered year. The section 303(d) list identifies water bodies that have experienced some level of degradation and require restoration. Water bodies on this list are increasingly assigned a higher priority for restoration resources obtained through other authorities in the Act, such as Section 319 or 104(b)(3). Within 13 years of being placed on the list, the State must develop a Total Maximum Daily Load (TMDL) document for the water body. The TMDL report could provide a blue print for restoration of water bodies in the Park.

The determination of whether a water body is considered “impaired” forms the basis for actions under the Clean Water Act. For water bodies in RMNP, this determination would be based on (1) “use classifications” and associated numerical standards adopted by the WQCC for specific waters in the Park, (2) Statewide narrative water quality standards, or (3) the antidegradation rule that applies to designated “outstanding waters” in the Park.

3. Use Classifications and Numerical Standards

Waters in the Park are currently classified for aquatic life, water supply, recreation and agricultural uses. Numerical water quality standards have been adopted for waters of the Park to protect the classified uses, based on “table value criteria” that are deemed to be generally protective of the specified use classification There are numerical standards for dissolved oxygen, pH, water temperature, E. coli, ammonia, chlorine, cyanide, fluoride, nitrate, nitrite, sulfide, boron, chloride, sulfate, asbestos, aluminum, antimony, arsenic, barium, beryllium, cadmium, chromium, copper, iron, lead, manganese, mercury, nickel, selenium, silver, thallium, uranium, and zinc. None of the numerical standards adopted to protect these uses appear to be exceeded by current chemical water quality. However, none of these uses are currently protected by numeric water quality standards for nutrients such as nitrogen. Ammonia and nitrate criteria apply to Park waters, however not necessarily from the standpoint of enrichment or eutrophication. The ammonia criteria is established to protect cold water biota from acute and chronic toxicity, and nitrite and nitrate criteria are established for the protection of domestic water supplies.

Option: The National Park Service could request the WQCC to adopt site-specific numerical chemical standards or biological criteria for waters in the Park at more stringent levels to protect areas needing special protection. A scientific demonstration would be needed showing such standards were necessary for protection. Standards would define desired conditions in terms of chemical and/or biological parameters. Some states are working on this, see, e.g., http://www.dep.state.fl.us/water/wqssp/nutrients/.

4. Statewide Narrative Standards

State water should be free from substances that can settle to form bottom deposits, form floating debris or scum, produce color or odor that create a nuisance, harm the beneficial uses, or are toxic to humans, animals, plants, or aquatic life. In addition, radioactive materials in surface waters must be maintained at the lowest practical level, and organic pollutants should not exceed the values listed in the Basic Standards for Organic Chemicals Table. Of the several statewide narrative standards set forth in section 31.11 of the Basic Standards and Methodologies for Surface Water, two appear potentially applicable:

- A prohibition of substances that “are harmful to the beneficial uses …”; and
- A prohibition of substances that “produce a predominance of undesirable aquatic life.”

Note that the reference to “beneficial uses” in the first of these narrative standards could be interpreted as referring back to classified uses, which would again require rulemaking action by the WQCC. The beneficial uses are the uses of state waters to be protected (like recreation or aquatic life), and the state use classifications are use-protected designations assigned to specific stream segments (like Class E – existing primary contact use or Class 1 – cold water aquatic life). Special use designations may be applied in stream segments that require additional protection, like outstanding waters.

Option: Provide a scientific demonstration to the WQCC that current levels of pollutants in waters in the Park are causing a violation of either narrative standard. A successful demonstration would result in a Section 303(d) listing for the waters in question.

5. Colorado Outstanding Waters Designation

The outstanding waters designation was applied to waters in the Park in 1981 and is intended to protect waters at "existing quality." From a legal standpoint, this would appear to protect existing water quality as of 1981.

Option: List the waters as impaired based on a scientific demonstration that the quality of water observed in 1981 had been degraded. Data can include chemical and biological indicators. The meaning of degraded in this context has not been specifically defined and would be open to interpretation and decision by the WQCC based on scientific evidence. Degradation is typically measured by chemical water quality. An argument could be advanced that changes in biological indicators demonstrate water quality degradation. Current water quality (chemical) data do not demonstrate degradation since 1981. A demonstration of degradation would result in a Section 303(d) listing.

6. Outcome of Section 303(d) listing and TMDLs

If the waters in the Park were included on the state's section 303(d) list due to impairment as described by numeric or narrative water quality standards or antidegradation, development of a TMDL would be required within 13 years. A TMDL identifies the overall reduction in pollutant loading necessary to attain applicable standards and allocates that pollutant load reduction between the identified sources of pollutants. A water body listed as impaired, particularly one for which a TMDL or watershed plan has been prepared and which has an existing, collaborative effort, is a high priority for any EPA funds for water restoration, and possibly other sources, such as USDA EQIP funds. This could be advantageous for RMNP waters if these funds were made available to help reduce air emissions affecting park waters. Implementation of the TMDL is not mandatory unless pollutants from "permitted discharges" can be reduced. Because the sources of atmospheric deposition to water bodies are air emission sources rather than water dischargers, identifying specific sources would be problematic and any emissions reductions required under the 303(d) listing program would always be "voluntary."

VI. Current Knowledge of Deposition Trends, Emissions, Transport and Attribution

A. Background

Atmospheric deposition is the process by which airborne pollutants are deposited to ecosystems. Atmospheric N deposition consists of both wet and dry components. Wet deposition occurs when pollutants are deposited in combination with precipitation, predominantly by rain and snow, but also by clouds and fog. Dry deposition of particles and gases occurs by complex processes that include settling, impaction, adsorption, and uptake by vegetation. Wet inorganic N deposition contains nitrate (NO_3) and ammonium (NH_4). These compounds originate from emissions of nitrogen oxides (NO_X) and ammonia (NH_3). Dry N deposition includes nitric acid (HNO_3), particulate nitrate (NO_3) and particulate ammonium (NH4). Total N deposition is likely to be underestimated at the Park because ammonia gas (NH_3) is not measured. In addition, organic N has not been measured at the Park, however studies at similar locations have shown that it may contribute 15-25% of total N deposition.[13]

Current total N deposition to the Park is estimated at 4.0 kg N/ha/yr (2000-2004 monitoring), with 3.1 kg N/ha/yr from wet deposition and 0.9 kg N/ha/yr from dry deposition, and the concentration of N in precipitation has been trending upward. Meeting the wet deposition loads recommended by the RMNP initiative as discussed in Chapter IV (2.7 kg N/ha/yr in 2012 and 1.5 kg N/ha/yr in 2032) to reverse the impacts of increasing N concentrations in the Park requires a 13% and 52% reduction of wet N deposition respectively.

There are numerous factors that affect deposition in a given geographic area: emission type, amount and distance from area of deposit, atmospheric chemical transformations of those emissions, topography, and local- and regional-scale meteorology including precipitation. Techniques do not exist to directly measure the contribution of a particular emission source to N deposition in the Park, therefore multiple technical analyses on existing and new data will be considered and interpreted to provide a weight of evidence upon which policy decisions can be based. "Weight of evidence" in this case refers to an assessment of multiple types of evidence, identifying strengths and weaknesses with the goal of better understanding a cause-effect relationship between emissions and deposition. This chapter summarizes key findings and presents information on trends, emissions inventories, and relevant existing modeling and other analyses; and finally addresses several important policy questions regarding source areas and types, and emissions reductions.

B. Key Findings

The key findings identified below are relevant pieces of information that are described in more detail in the "Technical Background Document" referenced below, or various data and studies described later in this chapter.

1. Deposition Monitoring and Trend Data

[13] Williams and others 2001; Sickman and others, 2001).

The Technical Background Document, "Nitrogen Deposition: Issues and Effects in Rocky Mountain National Park (2004) (http://www.cdphe.state.co.us/ap/rmnp/noxtech.pdf), describes the spatial distribution, composition, and temporal trends of N deposition at RMNP. Key findings from that report used National Atmospheric Deposition Program (NADP) and Clean Air Status and Trends Network (CASTNet) data through 2003, and are summarized as follows:

Spatial Distribution

- In Colorado, N deposition is generally higher on the east slope of the Continental Divide than on the west slope, however current deposition levels at all monitoring sites exceed natural levels.

- High-elevation sites, such as Loch Vale in RMNP, receive more wet N deposition than lower elevation sites, most likely due to the orographic effect of increased precipitation with elevation.

Composition

- Total N deposition at the Park is ~75% wet and ~25% dry deposition (although at Niwot Ridge dry deposition was shown to contribute as much as 47% to total deposition). Nitrate and ammonium contribute approximately equal amounts to wet N deposition. Nitric acid is responsible for about ~75% of dry N deposition, nitrate and ammonium the other ~25%. Ammonia gas is not currently measured, thus total deposition levels are underestimated.

Temporal Trends

- Nitrogen deposition to high-elevation Park ecosystems has been increasing by about 2% per year over the last two decades (statistically significant (p<0.05) trends in NADP wet deposition data at Loch Vale).

- Nitrate and ammonium concentrations in precipitation at the Park are increasing; however ammonium is increasing more rapidly (26% increase in wet nitrate concentrations in precipitation and 73% increase in wet ammonium concentrations in precipitation at the Beaver Meadows site between 1985-2002).

- Total (wet and dry) N deposition in the Park is highest in the summer months of June, July, and August.

Trend analyses including data through 2005 are also available, and are summarized as follows:

- Current deposition levels are well above the resource management goal for aquatic ecosystems.

- Nitrate and ammonium contribute equally to wet N deposition at the Park.

- Ammonium is increasing at a more rapid rate than nitrate.

- Total N deposition appears to be on the increase.

2. Source Category and Source Area Attribution Analyses

The primary analyses from which the following conclusions are drawn are the State's emission inventory data, the Western Regional Air Partnership's (WRAP's) Particulate Matter Source Apportionment (PSAT) modeling study, and preliminary studies under the Rocky Mountain Atmospheric Nitrogen and Sulfur Study (RoMANS) being conducted by multiple partners[14] and coordinated by the National Park Service. Both analyses are discussed later in this chapter.

- Highest NH4 and NO3 wet deposition at Loch Vale generally occur during spring (March-April) and summer (July-August) (01-03 sampling) when easterly upslope flow is more frequent.

- Current data do not directly identify specific emissions sources that contribute to N deposition in Rocky Mountain National Park. However, modeling analyses, conducted for regional haze planning, indicate that Colorado sources contribute a significant portion of the nitrate (>30%) and ammonium (>50%) found in fine particulates that affect visibility at RMNP. While this assessment does not explicitly apply to deposition, it is an important indicator that a similar relationship may exist between Colorado sources and wet deposition in the Park.

- Of the 55 percent of the modeled particulate NH4 predicted to be contributed by Colorado sources to regional haze at RMNP, 10 percent comes from mobile sources and 45 percent comes from area sources, including agricultural sources. Midwestern states contribute, by comparison, less than 10 percent of area source NH4.

- Of the 31 percent of the modeled particulate NO3 expected to come from Colorado, 25 percent comes from point sources, 15 percent from mobile sources and less than 10 percent from area sources.

- Colorado's source category relative contributions to total molar N from NOx and NH3 sources are: 19% point sources, 34% mobile, 23% agriculture, and 24% in other area sources.

- Modeling sensitivity runs, covering a two week intensive monitoring period, using inert tracers to represent NOX and NH3 emissions, indicate that Colorado sources contribute significantly (>50% NOx and >30% NH3) to nitrogen concentrations in

[14] EPA, NOAA, USGS, USDA Forest Service; Cooperative Institute for Research in the Atmosphere, Colorado State University; State of Colorado Department of Public Health and Environment; Air Resource Specialists; University of California at Davis; Community Collaborative Rain, Hail and Snow Network.

RMNP. The nature of this analysis (no deposition or chemical conversion) likely underestimates the relative contribution from Colorado.

- It is clear that to decrease N deposition in RMNP, NOx and/or NH3 emissions decreases need to occur. Studies and data in the scientific record discussed below indicate a strong possibility that a significant portion of N deposited in the park comes from areas east of the Park.

C. Current Deposition Trends

As discussed in Chapters 3 and 4, the parameter of interest for purposes of the RMNP Initiative is wet deposition. The monitoring techniques and historical data record are sound, allowing for reasonably certain tracking of changes. While total deposition would be the most ideal parameter, techniques and data are less certain for dry deposition, and the proportion of wet to dry deposition is likely to remain relatively constant. Therefore, as wet N deposition declines, dry N deposition is also likely to decline.

Wet deposition is a calculated value obtained by multiplying a measured concentration of a chemical species by the precipitation amount. In RMNP, NADP samplers collect precipitation to be chemically analyzed in the laboratory to determine concentrations of various chemical species, in terms of mass per volume of water. Using separate precipitation event measurements, wet deposition is reported in terms of mass of a species per unit area over time, usually kilograms per hectare (10,000 square meters) per year (kg/ha/yr). Because precipitation events and amounts can vary dramatically from year to year, scientists find it useful when interpreting trends to track changes for both precipitation and the concentrations of the chemical species responsible for air pollutant deposition.

Figures 1-4 illustrate the change in concentrations of nitrate and ammonium in precipitation on a spatial and temporal basis, across the contiguous United States from 1984 to 2005. Concentrations are plotted, rather than wet deposition, to minimize the effects of changes in precipitation. Nitrate concentrations have decreased in the upper Midwest but have increased over the central Rockies and central plains. Ammonium concentrations have increased over much of the country, including the Rockies, but have increased most over eastern Colorado and the central plains since 1984. A nonparametric Seasonal Kendall Trend test shows that concentrations of nitrate and ammonium have increased significantly from 1985 to 2004 at the Loch Vale monitoring site. Over this time period, nitrate concentrations have increased 23 percent and ammonium concentrations have increased 57 percent.[15]

[15]NADP Quality Assurance Manager, personal communication.

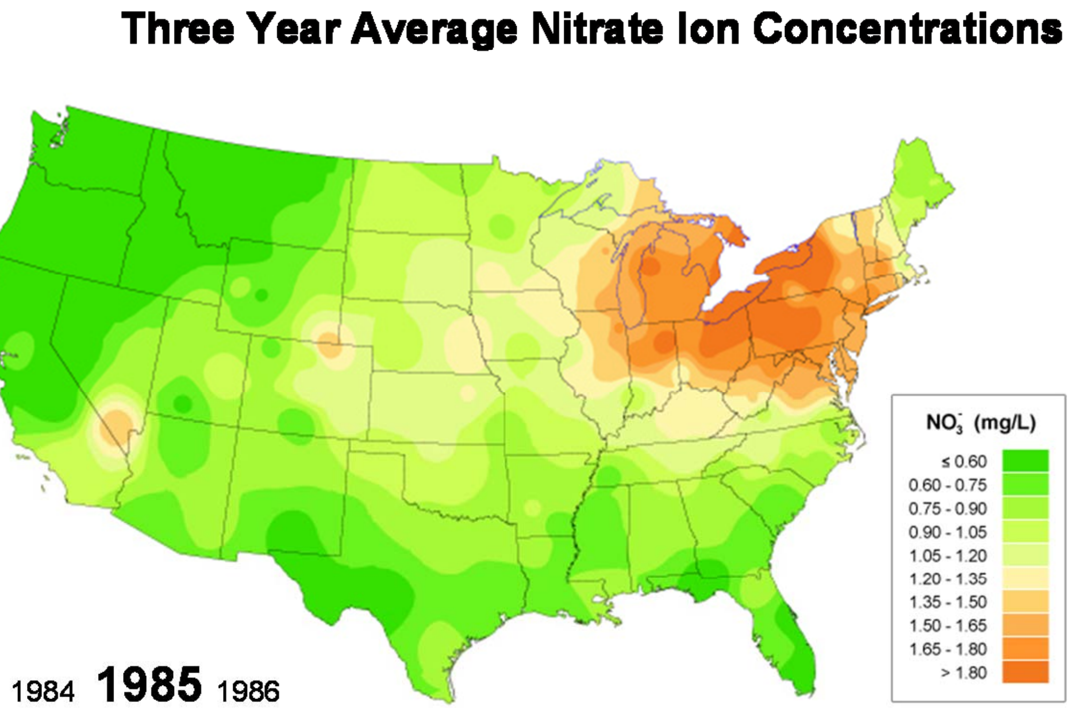

Figure 1: Nitrate Ion Concentrations, 1984-1986

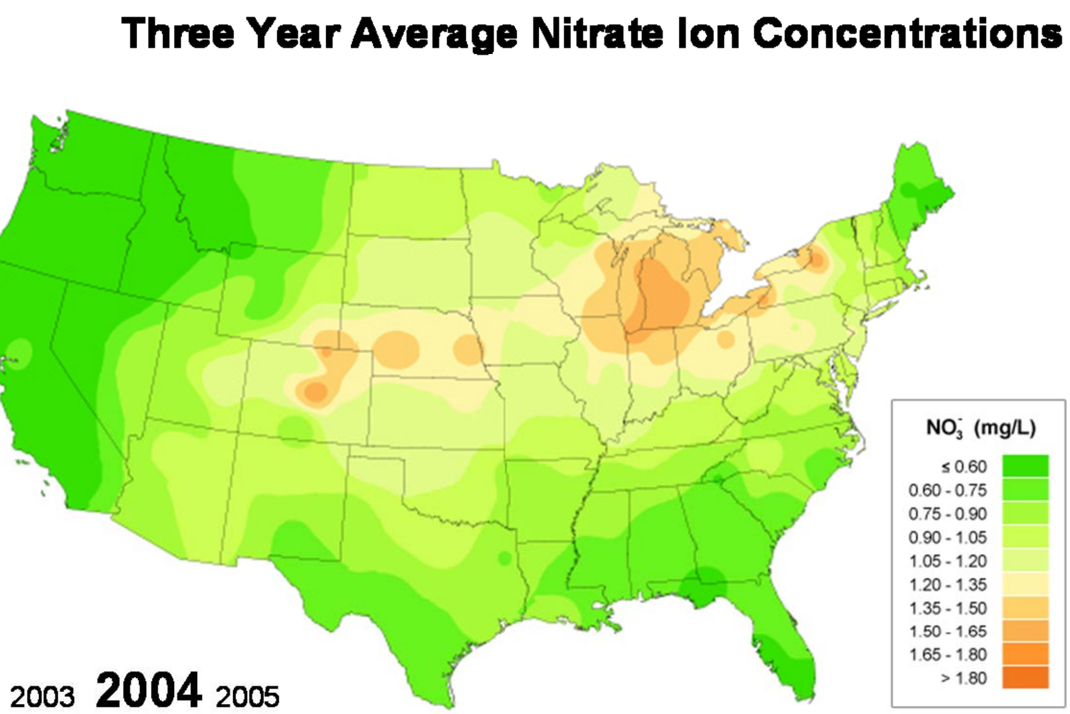

Figure 2: Nitrate Ion Concentrations, 2003 - 2005

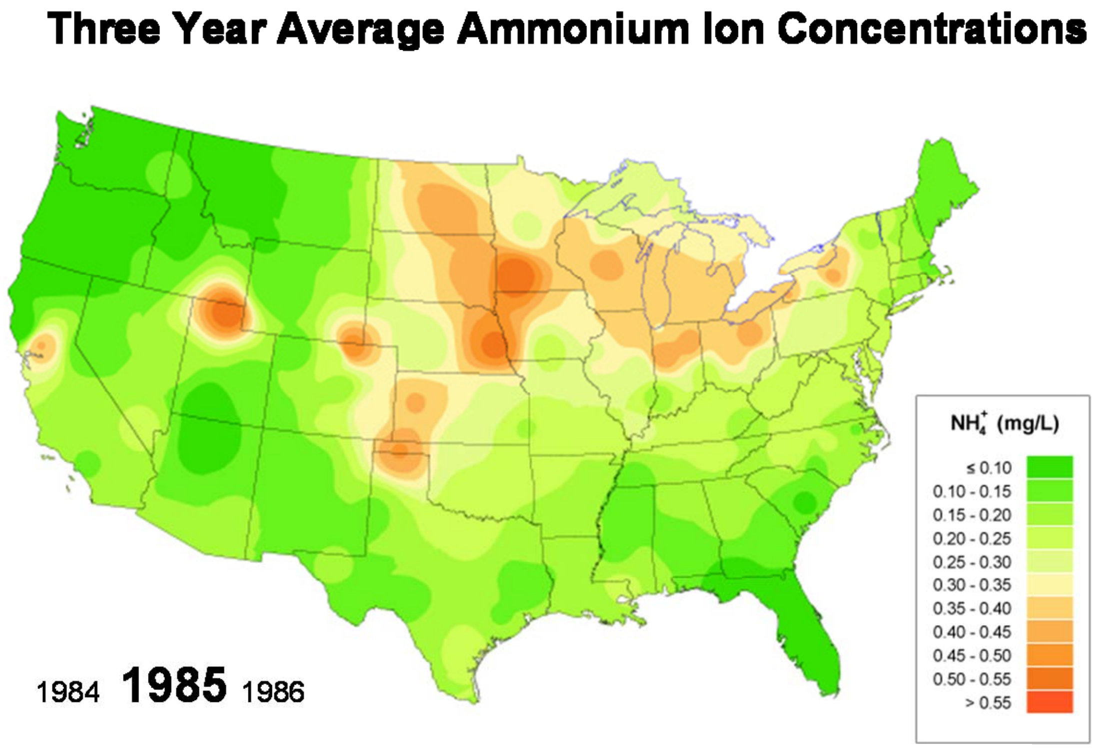

Figure 3: Ammonium Concentrations, 1984 – 1986

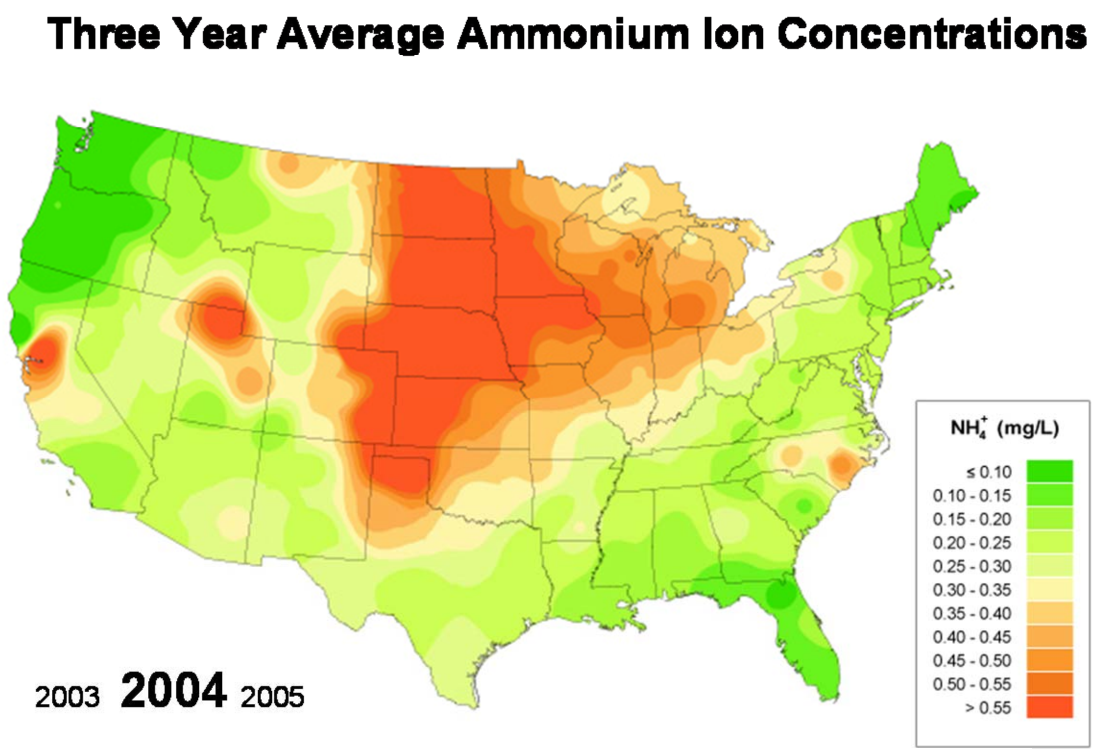

Figure 4: Ammonium Concentrations, 2003 – 2005

Figure 5 shows concentrations of nitrate and ammonium in precipitation (expressed as N) at the Loch Vale site. Nitrate concentrations appear to be increasing at a steady rate over the last two decades, while ammonium concentrations have increased at a more rapid rate in the past ten years.

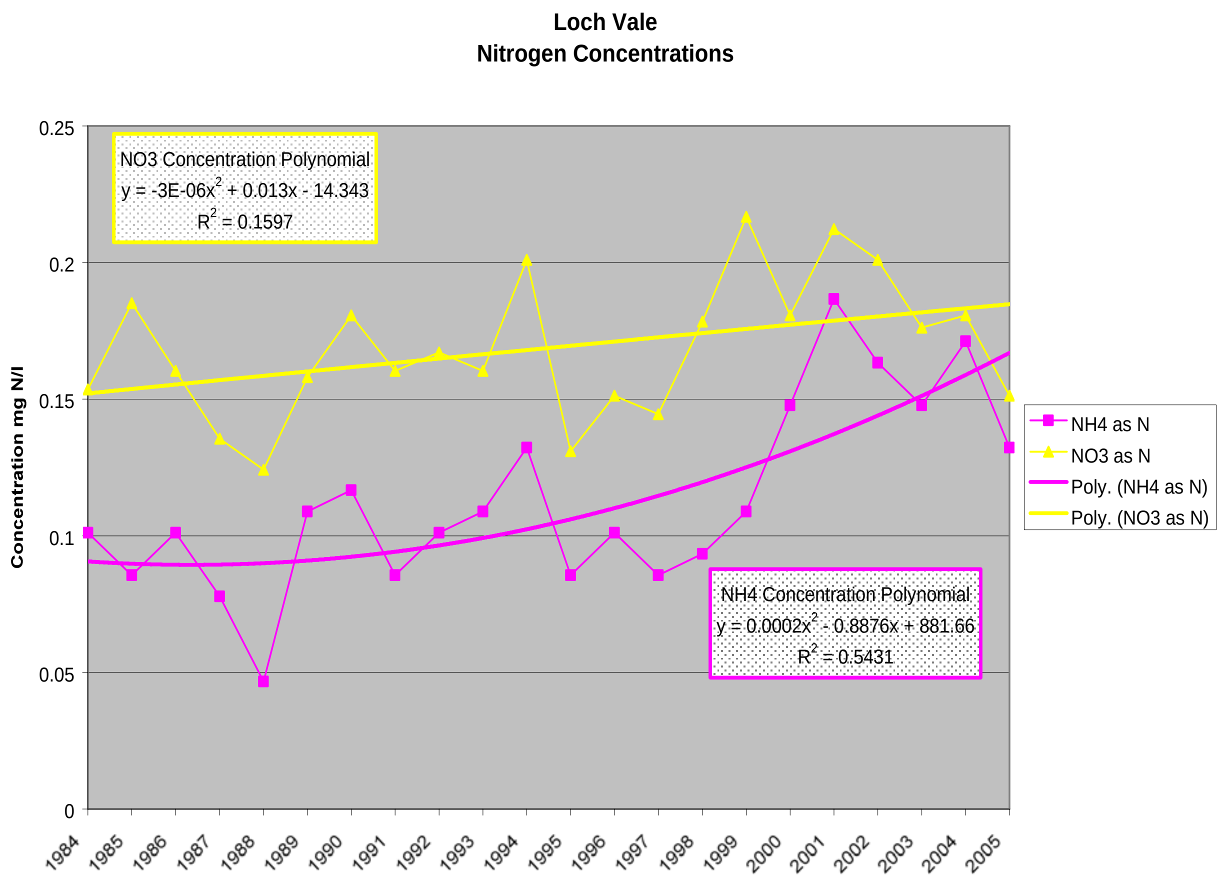

Figure 5

Ecosystem effects are influenced by the amount of deposition, not just the concentration. For purposes of the resource management goal, the relevant parameter for the Park is the deposition. Figure 6 shows ammonium, nitrate and total N (the sum of ammonium and nitrate) in wet deposition, as well as precipitation for the 22-year period of record at Loch Vale in RMNP. There is considerable year-to-year variation in deposition and precipitation. Large changes in precipitation are accompanied by similar changes in the deposition, illustrating the dependence of wet deposition on precipitation amount, as discussed above.

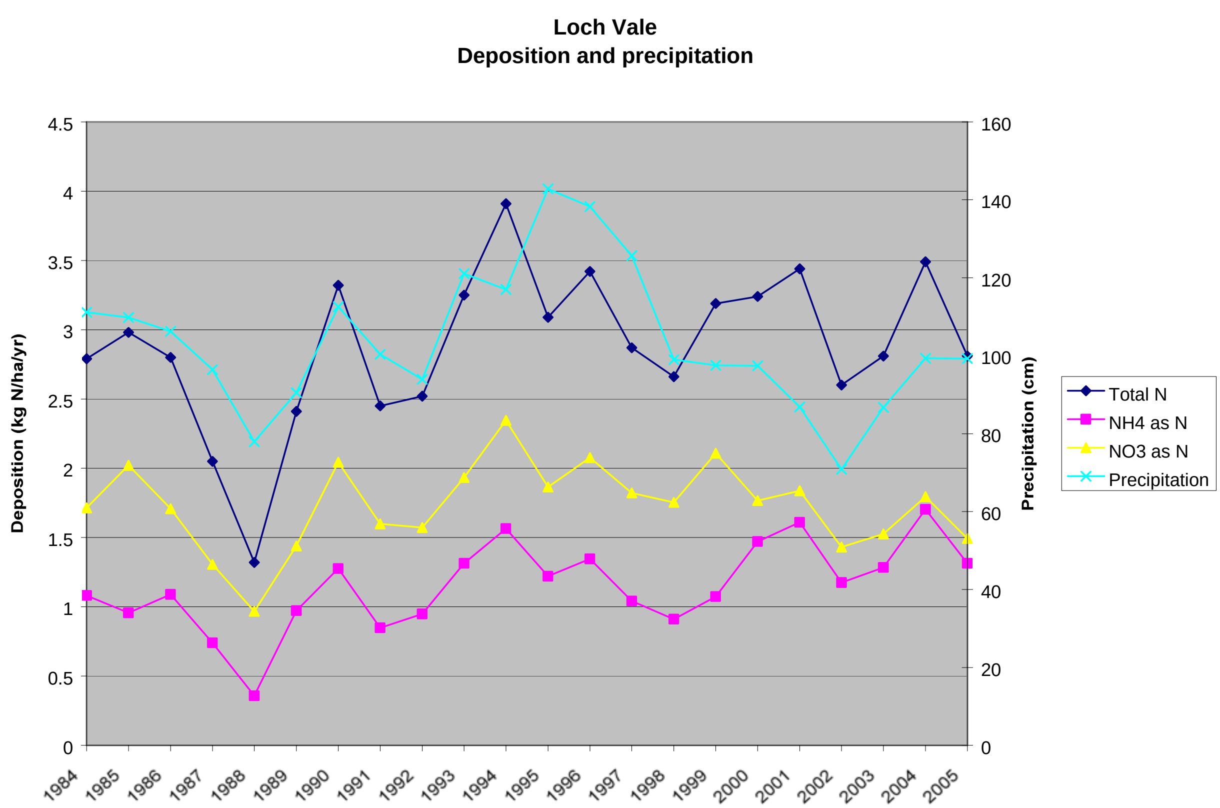

Figure 6

Figure 7 plots the same data as figure 6, but superimposes a polynomial curve fit to indicate whether the measured levels are steadily increasing, decreasing or changing direction. Ammonium wet deposition appears to be steadily increasing over the period. Nitrate wet deposition appears to have leveled off and then decreased slightly since the mid-1990s. Total wet nitrogen deposition has increased and then leveled off. However, this may be due to a decline in precipitation that occurred during the same time period.

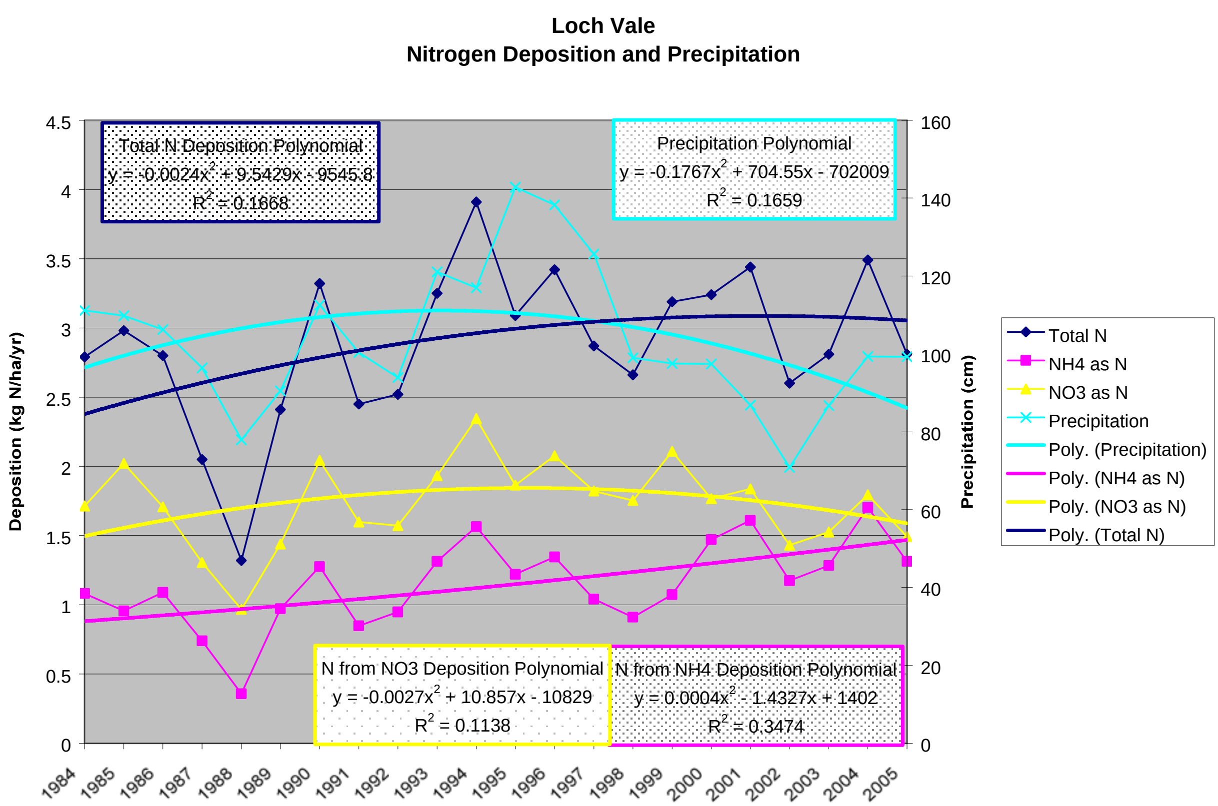

Figure 7

Figure 8 is similar to Figure 7 except that the concentrations have been converted to normalized deposition to partially address the confounding effect of changing precipitation amounts over time. Normalized deposition can be calculated by taking the annual concentration, reported in mg/l and multiplying by the long term average precipitation amount. By using the normalized wet deposition, the effects of changing emissions on concentrations can be tracked, while still expressing those changes in terms of deposition.

While the curve fit shown here indicates that normalized deposition of total nitrate is increasing, it is encouraging to note that the annual values have decreased since 2001. However, ammonium and total N continue to increase.

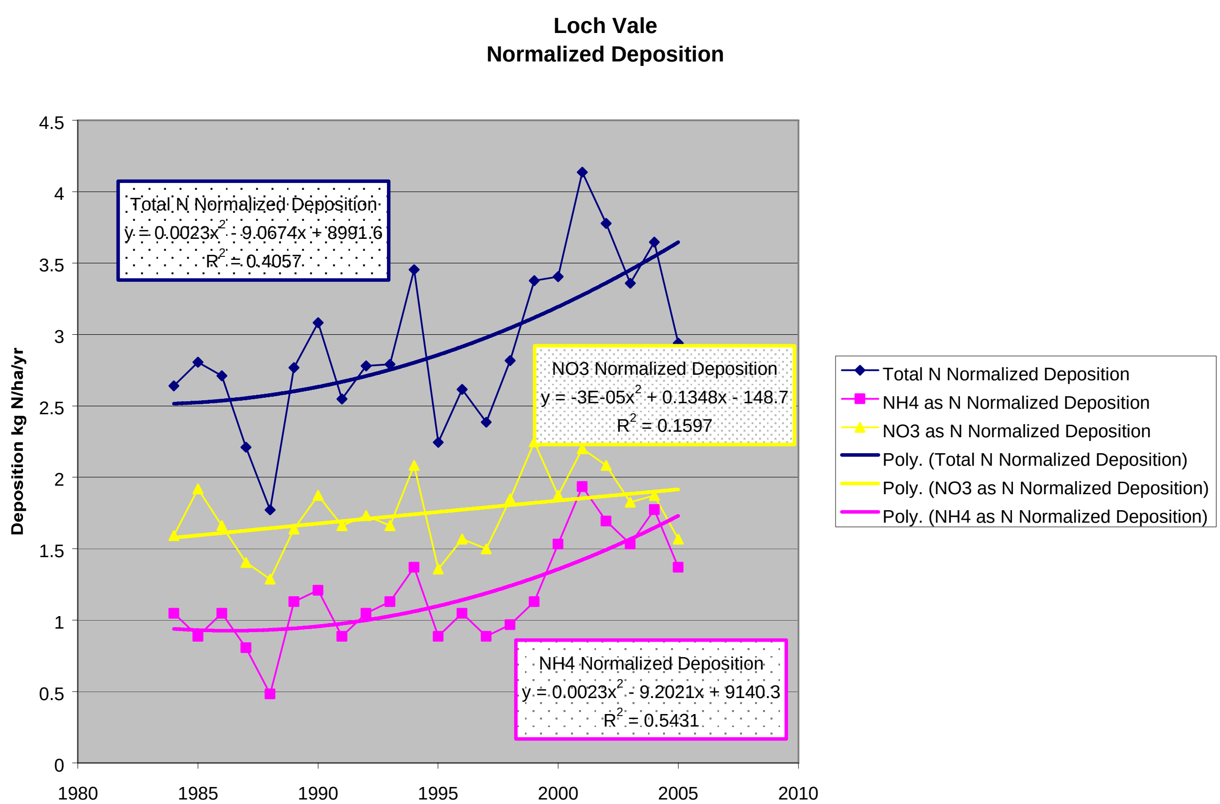

Figure 8

In spite of the complexities associated with characterizing trends in nitrogen deposition at RMNP, it is clear that (1) current deposition levels are well above the resource management goal for aquatic ecosystems;(2) nitrate and ammonium contribute equally to wet N deposition at the Park; (3) ammonium is increasing at a more rapid rate than nitrate; and (4) Total N normalized deposition is on the increase.

D. Emission Inventories

1. State and Front Range Inventories

Tables 1-3 display statewide and Front Range emissions from the Western Regional Air Partnership's (WRAP) 2002 emission inventory, which is considered to be the most comprehensive available. Table 1 provides emission inventory data by county for six criteria pollutants for each county in the state. Front Range counties are shaded in Table 1 for easier reference. Table 2 provides an emission inventory for each source sector: point sources, mobile (on & off road) sources, and area sources for the entire state. Table 3 provides the same review as Table 2 for the emission inventory, but it is limited to the Front Range counties. The inventory does have some inherent limitations since data and emission factors for some pollutants and source categories are uncertain. For instance, the area source inventories for agriculture are based on assumptions and emission factors that have very little data or peer-reviewed research.[16] The 2002 WRAP Statewide NH3 emissions presented in the table below are below the total NH_3 emissions CDPHE presented at stakeholder meetings because biogenic (native soils) and domestic NH3 sources are not included. It is important to note, however, that the table presented here does include all potentially controllable anthropogenic emission sources. Also, analyses (WRAP PSAT) comparing effects from Colorado versus other states do not include these categories (native soils, etc.) from the other states. As shown in Table 3, the Front Range contributes a significant portion of the inventory for all pollutants (63 percent of the state's NO_x and 44 percent of the state's NH_3.

Table 1: Statewide Emissions & Front Range (shaded in gray) Emissions
2002 WRAP Emissions Inventory for Colorado
Point, Area and Mobile Sources

County	VOC [tpy]	NOX [tpy]	CO [tpy]	SO2 [tpy]	PM10 [tpy]	NH3 [tpy]
Adams	25,011	29,000	122,071	19,637	19,137	1,540
Alamosa	1,454	1,116	8,632	59	3,585	334
Arapahoe	26,026	18,672	161,751	1,693	22,076	879
Archuleta	1,023	637	7,244	27	1,896	506
Baca	1,726	1,436	3,813	57	8,816	1,488
Bent	995	1,319	4,109	67	2,697	670
Boulder	19,225	15,111	87,389	4,754	13,518	515

[16] National Research Council (2003), Air Emissions from Animal Feeding Operations: Current Knowledge, Future Needs. National Academy Press, Washington, D.C).

Table 1: Statewide Emissions & Front Range (shaded in gray) Emissions 2002 WRAP Emissions Inventory for Colorado Point, Area and Mobile Sources						
County	**VOC [tpy]**	**NOX [tpy]**	**CO [tpy]**	**SO2 [tpy]**	**PM10 [tpy]**	**NH3 [tpy]**
Broomfield	2,141	1,639	12,473	106	1,146	65
Chaffee	1,628	958	10,650	124	2,965	326
Cheyenne	2,369	3,359	5,426	30	8,928	746
Clear Creek	2,447	2,991	31,881	79	2,230	183
Conejos	865	668	4,896	26	3,480	361
Costilla	754	530	4,328	23	1,517	496
Crowley	473	315	2,040	7	1,783	498
Custer	548	210	2,892	11	813	169
Delta	2,219	1,629	13,948	131	5,368	1,063
Denver	34,052	32,483	200,219	7,865	12,100	1,710
Dolores	796	662	2,953	11	1,943	516
Douglas	10,292	9,583	77,487	522	13,327	432
Eagle	4,777	5,000	43,232	226	7,137	352
Elbert	1,785	1,499	12,527	42	6,924	529
El Paso	36,716	28,316	215,801	15,083	29,054	1,196
Fremont	2,569	3,959	16,803	1,815	3,841	398
Garfield	13,044	10,320	40,313	295	6,489	428
Gilpin	628	600	4,390	33	1,061	12
Grand	1,851	1,968	13,536	138	3,409	210
Gunnison	1,826	1,120	12,019	62	2,792	355
Hinsdale	1,012	95	3,100	6	222	8
Huerfano	1,073	2,294	10,139	90	1,242	337
Jackson	772	442	3,396	13	579	168
Jefferson	29,944	20,932	172,168	3,897	16,575	832
Kiowa	990	1,067	3,903	130	11,282	1,038
Kit Carson	2,940	3,120	19,617	81	19,096	2,326
Lake	2,164	2,017	24,784	59	1,410	174
La Plata	3,473	5,768	11,766	116	6,441	486
Larimer	18,068	15,355	108,478	2,068	24,730	1,976
Las Animas	1,864	4,297	12,650	134	1,990	519
Lincoln	1,746	1,561	9,344	45	9,181	689
Logan	2,890	3,730	14,730	160	14,275	4,395
Mesa	9,830	7,574	55,421	2,465	11,994	752
Mineral	1,025	241	4,393	11	311	11
Moffat	3,043	21,734	11,962	10,454	2,224	506
Montezuma	2,567	2,018	16,369	90	4,460	332
Montrose	2,580	2,917	15,194	1,593	7,763	790
Morgan	3,735	9,512	19,299	15,078	8,378	5,402
Otero	1,901	1,693	9,881	85	4,695	1,370
Ouray	642	376	4,488	16	947	459

Table 1: Statewide Emissions & Front Range (shaded in gray) Emissions 2002 WRAP Emissions Inventory for Colorado Point, Area and Mobile Sources						
County	**VOC [tpy]**	**NOX [tpy]**	**CO [tpy]**	**SO2 [tpy]**	**PM10 [tpy]**	**NH3 [tpy]**
Park	1,612	858	11,333	36	3,322	387
Phillips	973	917	3,000	35	8,545	1,121
Pitkin	1,577	1,237	11,604	83	2,256	178
Prowers	2,004	2,227	7,892	66	9,962	2,299
Pueblo	10,001	17,219	65,920	17,506	11,351	725
Rio Blanco	4,537	5,627	8,451	46	1,671	540
Rio Grande	1,620	965	8,081	128	3,852	421
Routt	2,006	10,588	14,078	3,002	4,286	392
Saguache	1,086	806	6,236	26	3,742	683
San Juan	881	224	4,038	10	288	869
San Miguel	1,345	831	5,909	32	1,607	335
Sedgwick	790	1,209	4,629	51	5,289	909
Summit	2,865	2,631	27,101	117	4,676	362
Teller	1,772	1,145	12,067	74	3,131	331
Washington	2,734	2,450	7,679	79	14,339	1,537
Weld	83,795	32,204	98,784	893	46,328	16,238
Yuma	5,313	4,761	7,696	95	18,254	6,153
Statewide Total	414,412	367,741	1,958,406	111,794	478,723	72,027
Front Range Total	299,008	230,025	1,341,840	89,101	217,720	31,510
FR [percent of statewide]	72.2%	62.6%	68.5%	79.7%	45.5%	43.7%

Note: PM2.5 emissions included in PM10 emissions.

	Table 2: 2002 WRAP Emission Inventory - Colorado Statewide					
	VOC [tpy]	**NOX [tpy]**	**CO [tpy]**	**SO2 [tpy]**	**PM10 [tpy]**	**NH3 [tpy]**
Point	91,749	117,868	35,950	97,011	-	539
Area	183,388	45,469	129,653	8,163	469,685	67,128
Mobile (On-road)	100,836	141,824	1,399,807	4,149	3,765	4,317
Mobile (Non-road)	38,438	62,581	392,996	2,472	5,273	43
Total:	414,412	367,741	1,958,406	111,794	478,723	72,027

	Table 3: 2002 WRAP Emission Inventory - Front Range					
	VOC [tpy]	NOX [tpy]	CO [tpy]	SO2 [tpy]	PM10 [tpy]	NH3 [tpy]

Point	75,177	65,675	18,988	78,036	-	427
Area	131,599	29,781	79,193	6,589	212,307	27,831
Mobile (On-road)	69,333	98,780	947,101	3,100	2,549	3,227
Mobile (Non-road)	22,899	35,789	296,558	1,376	2,864	25
Total:	299,008	230,025	1,341,840	89,101	217,720	31,510
Percent of Total:	72.2%	62.6%	68.5%	79.7%	45.5%	43.7%

The above tables are expressed in tons of the compounds NO_x and NH_3, whereas tons of N is the more relevant parameter for purposes of examining nitrogen deposition at RMNP. In other words, the absolute amount of NOx and NH3 emissions does not necessarily give a clear indication of the amount of N contained in airborne particulate matter or formed by secondary chemical reactions and then deposited into the ecosystem. However, Figures 1 and 2 show for the Front Range and statewide respectively, the actual magnitude of molecular or molar N coming from source categories. The term molar N is used to describe the relative amount of nitrogen based on the molecular weight. For example, to calculate the amount of nitrogen from NOx emissions (assumed to be mostly NO2) we multiply the NOx emissions in tons per year by 14/46. The NOx molecular weight ratio is determined by the atomic weight of N = 14 and O = 16, thus NO2 = (14 + 2*16) = 46. In Figure 2, Colorado's source category relative contributions to N are: 19% point sources, 34% mobile, 23% agriculture, and the remainder in the other area sources.

2002 Colorado Front Range Molar Nitrogen from NOx and NH3 Sources

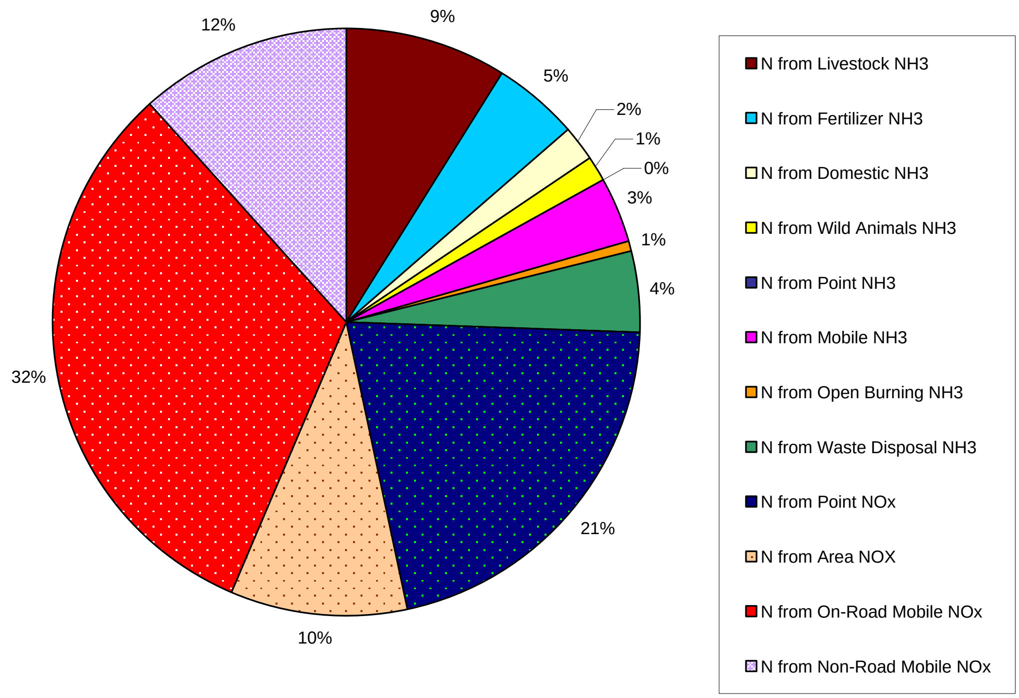

Figure 1.

2002 Colorado Statewide Molar Nitrogen from NOx and NH3 Sources

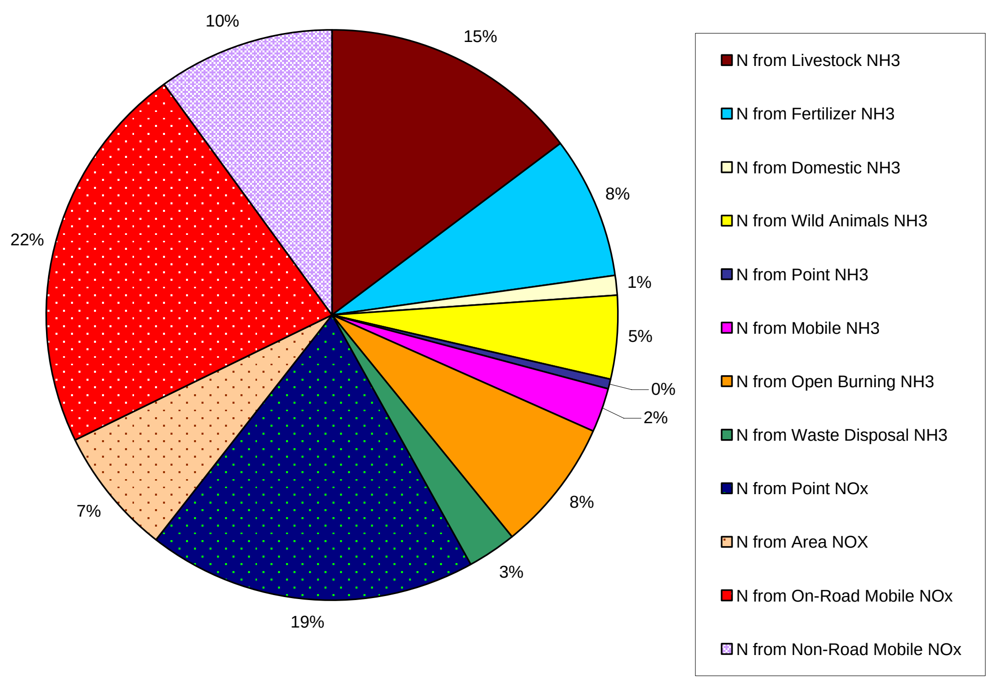

Figure 2.

To the extent there are not reliable inventories for NH_3 emissions, inventories and trends regarding the sources themselves are relevant. For example, cattle (Figure 3) and harvested cropland (Figure 4) appear to be on the decrease, while swine (Figure 5) has increased threefold in the last two decades. Additional graphics on agricultural trends, including information for selected counties, is available in Appendix T.

Also, recent demographic trends show an increase in the developed landscape within our state. Between 1990 and 2000, according to the Denver Regional Council of Governments, the nine counties of the Denver metropolitan area added 555,700 people and 203,700 new households. During the 1990s, this nine county region, including Boulder, Gilpin, Clear Creek, Jefferson, Douglas, Arapahoe, Adams, Denver and Broomfield, alone, added 90 square miles of urban area, growing from 410 square miles in 1990 to 500 square miles by 2000. Of the more than 200,000 new households added to the region, 45 percent located in areas not previously urbanized. It is predicted that by 2022, Colorado will lose another 3.1 million acres of agricultural land to urban sprawl, according to Environment Colorado Research and Policy Center.

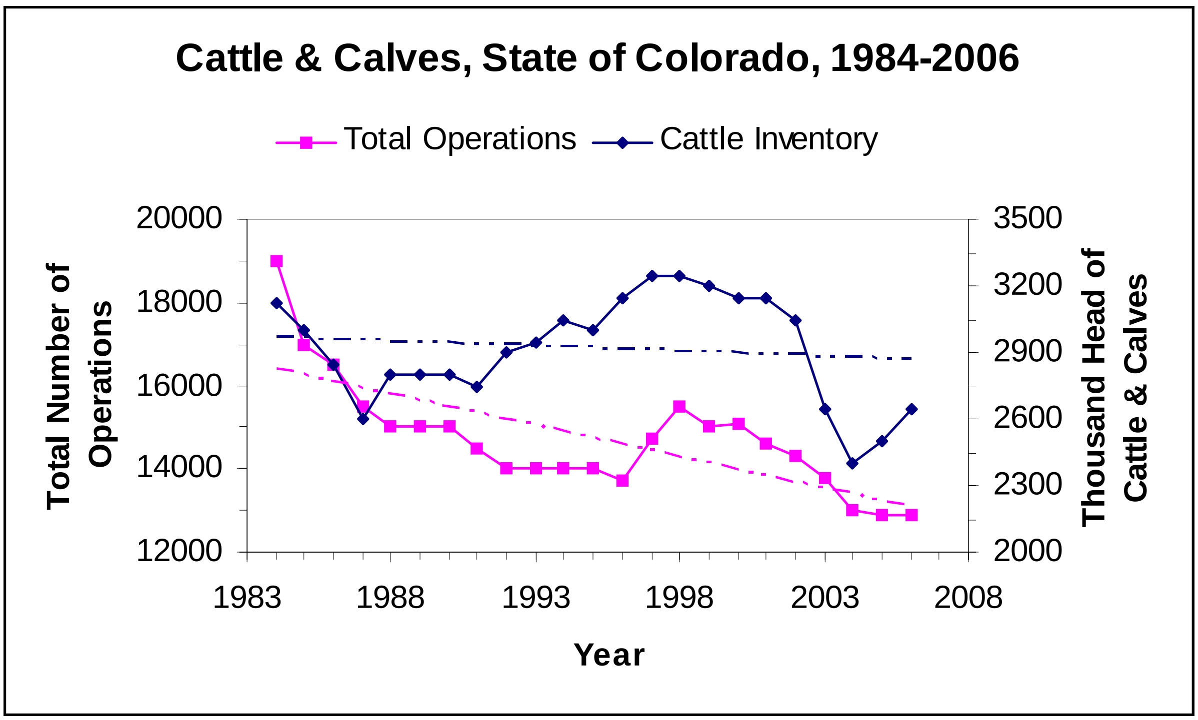

Figure 3 (source: USDA National Agricultural Statistics Service)

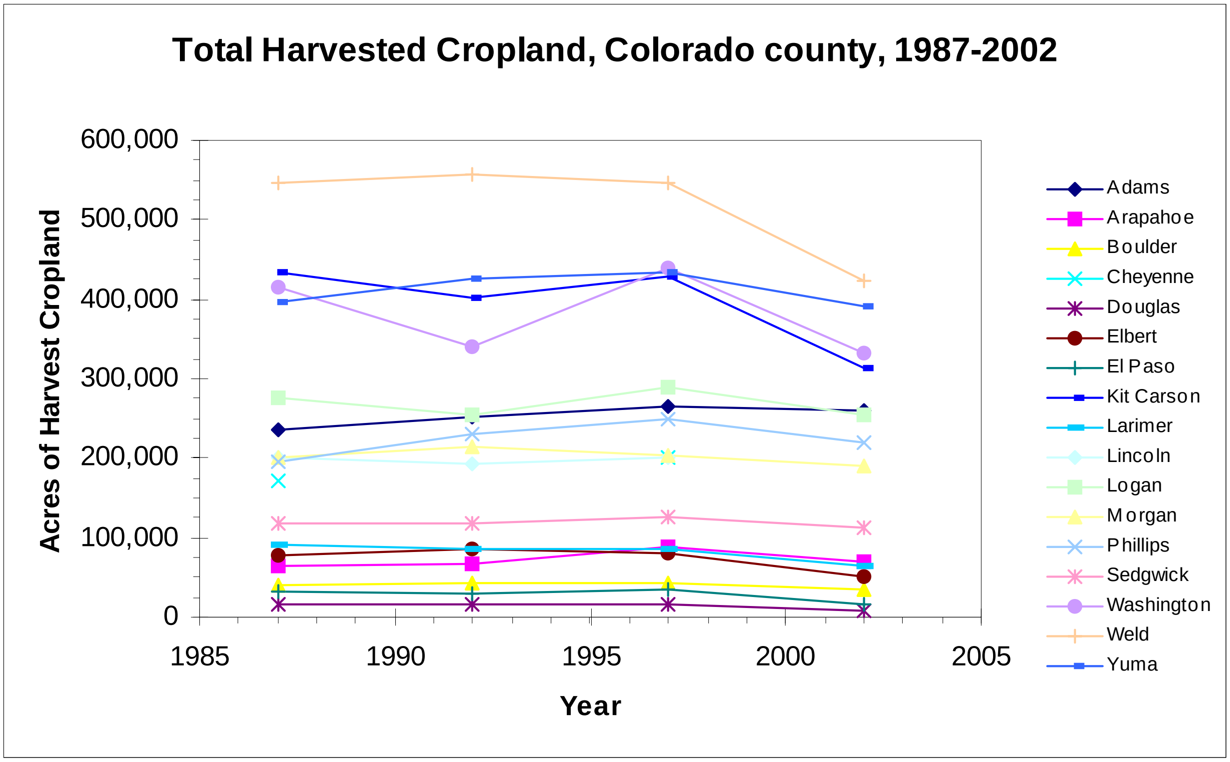

Figure 4 (source: USDA National Agricultural Statistics Service)

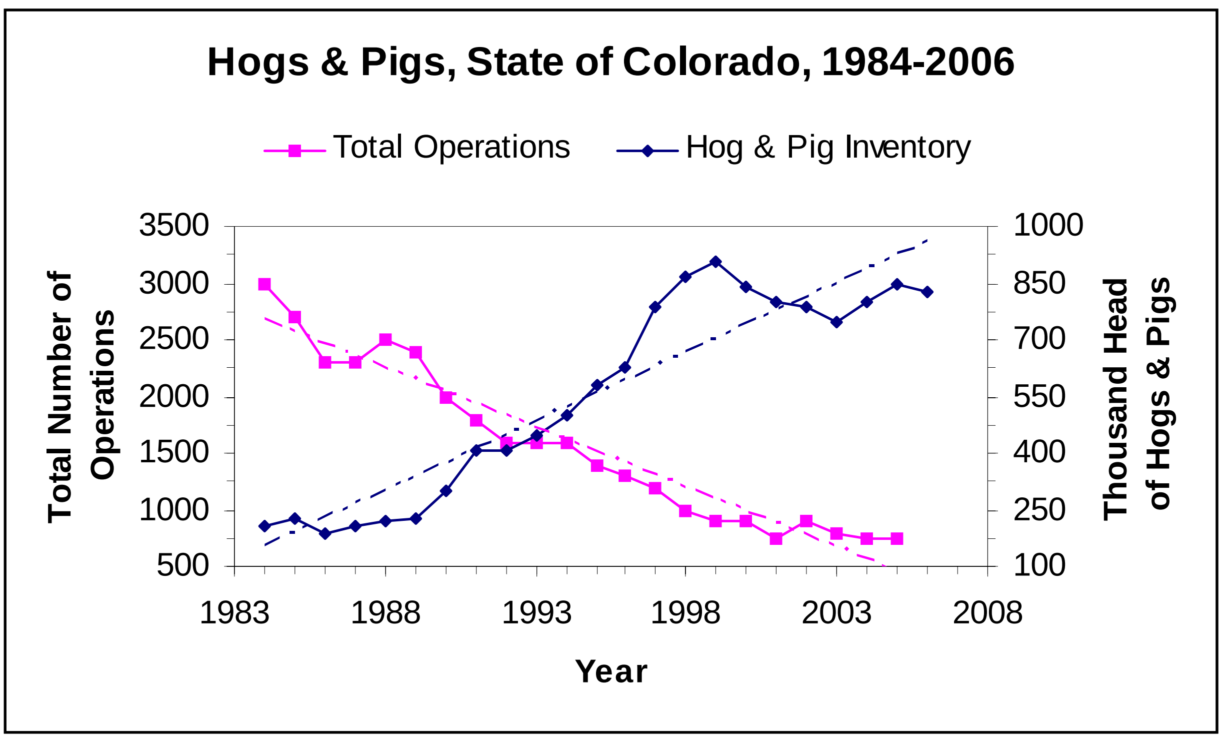

Figure 5 (source: USDA National Agricultural Statistics Service)

2. In-Park Emissions

a. Mobile Sources

Rocky Mountain National Park has over 3 million visitors per year. These individuals arrive at and tour the Park and its surrounding areas primarily in gasoline and diesel powered vehicles. In addition, the community of Estes Park borders the Park on the east side and attracts many visitors. These mobile sources contribute to the emissions of NO_x and it is likely that some of these air pollutant emissions are a part of the pollutants deposited in the Park, adding to the nitrogen loading in Park ecosystems.

RMNP has taken many steps to reduce mobile source emissions. The park has created a visitor shuttle bus (in-park Bear Lake corridor only) to include additional transportation from downtown Estes Park into the Park (Hiker Shuttle). The Town of Estes Park provides a free Shopper Shuttle to provide access from local hotels and campgrounds to the downtown area, allowing visitors to park their private vehicles at their hotel or campground and use the free shuttle system to access many different areas of the Park.

This enhanced shuttle service proven popular with visitors. Over 9,300 people rode the Hiker Shuttle and almost 19,000 people rode the Shopper Shuttle during its inaugural summer season. During the complete 2006 season the combined shuttle system (Shopper/Hiker shuttles and original in-park shuttles along Bear Lake corridor) ran daily from June 16 through October 1 with over a quarter million riders.

RMNP has been striving to use new, more environmentally-friendly automobile technology in its own fleet of vehicles. In 2004, the Park was a partner for the Clean Cities Colorado event in Estes Park where multiple kinds of alternative fuel vehicles were displayed for the public and various manufactures presented and distributed information on greener automotive technology. Currently, the Park's alternative fuels vehicle fleet contains 16 propane, 2 dual fueled natural gas (NG or unleaded), 4 hybrid, 1 electric, and approximately 60 flex-fuel (gasoline/E-85, 85% ethanol) vehicles. However, these E-85 vehicles do not currently run on ethanol because a fueling system is not yet available. The Park is currently working on a plan to implement a fueling system in the near future.

All of the Park's diesel engines use biodiesel. The west side of the Park used 7,206 gallons of biodiesel and the east side used 32,850 gallons of biodiesel in 2004. In 2005, the biodiesel type used was very corrosive to vehicle engines and fueling systems so it was discontinued for the season.

RMNP is investigating new options for using alternative fuels for the current shuttle bus fleet. Currently, no alternative fuel technology exists that would allow buses to operate effectively on the steep grades of the park's mountain roads.

These efforts help to reduce emissions of NO_x from mobile sources in the Park and around the Park. Mobile source emission reduction efforts will continue to grow in the future and provide a benefit to decreasing deposition in RMNP.

b. Stationary Sources

The Alpine Visitor Center within RMNP generates electricity to power the facilities at this very remote location atop Trail Ridge road. Two new energy efficient diesel powered generators were recently installed and burn bio-diesel as fuel during the summer months. The Alpine Visitor Center is closed during the fall, winter and spring months. The administrative facilities within RMNP are powered and heated with electricity produced by local hydro-electric plants.

c. Natural Sources

Natural background emissions of N for the western U.S. have been estimated at around 0.2 kg/ha/yr. These emissions estimates include contributions from animal and plant sources. Nitrogen emissions to the atmosphere from natural sources in the Park should be similar today as they were historically under natural conditions. Currently there are less than 4,000 large ungulates in the RMNP area.[17]

d. Climate Friendly Parks Program

RMNP has recently agreed to participate in the Climate Friendly Parks (CFP) program which teams with the U.S. EPA as part of the NPS Green Parks Partnership Program. The CFP program encourages and enables national parks to develop both short and long term, comprehensive strategies to reduce greenhouse gas (GHG) and criteria air pollutant emissions. Also, the program includes a commitment on the part of the park to educate the public about what actions the park is taking to mitigate emissions and to communicate why the issues of climate change and air pollution are so important. Participating in a CFP program includes: holding a technical workshop (which is planned to occur in March 2007) to educate staff and the public; completion of a GHG/criteria air pollutant emissions inventory; and creation of an action plan to identify initiatives, milestones, and track success.

E. Calculations and Related Modeling Analyses

1. Projected Reductions in NO_x Emissions

The Colorado Department of Public Health and Environment has estimated that NO_x reductions will occur from air pollution controls that have been adopted at either the State or Federal level but not yet implemented. These predicted reductions are as follows:

- 30% NOx reduction in western US by 2018

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[17] According to the latest WRAP ammonia inventory (2005) and the Carnegie Mellon University ammonia model (http://www.cmu.edu/ammonia/), this number of animals is estimated to produce less than 8,000 kg N/year, a fraction of the estimated 4 million kg N/year produced by domestic livestock in captive animal feeding operations in Colorado.

- 28% NOx reduction in metro Denver by 2022, fueled by 71% reduction from mobile and 33% growth in stationary
- 23% NOx reduction in Front Range by 2012, fueled by 50% reduction from mobile sources

Other potential reductions will have to be assessed as they are identified, such as any reductions of NO_x from BART actions or other actions necessary to meet regional haze goals. Currently, there is no analysis that would directly quantify the effects of emissions reductions in any geographic area on deposition in any geographic area.

2. Rollback Analysis

A simple rollback analysis can provide us a potential estimate of how planned reductions of NO_x will affect nitrogen deposition loading The five year average from 2000-2004 wet N deposition rate at the RMNP Loch Vale site is 3.1 kg N/ha/yr wet deposition. Given that at the RMNP Loch Vale monitoring site, NH4 and NO3 each contribute approximately equally to the mass of wet deposited N, the projected 23% reduction in NO_x noted above may be sufficient to achieve a target load of 2.7 kg/ha/yr in 2012. While this type of analysis is helpful to understand the positive impact of the emissions reductions, it makes several unlikely assumptions, including:

- NH3 emissions remain stable (no increases or decreases) and NH4 deposition does not continue to increase;
- There is a linear relationship between emissions of NO_x in the region, and the amount or rate of deposition in RMNP (concentrations in precipitation). In other words, this assumption does not consider the atmospheric chemistry that impacts what portion of emissions are ultimately deposited.
- Nitrogen deposition in the Park is attributable to local emissions and there is no long range transport of emissions into the Park, or all western states have the same net reduction of NO_x between now and 2012.
- All emissions reductions are spatially uniform.

Assuming a uniform average 23% reduction of NO_x, then:

- ½ x 3.1 x 0.23 kg N/ha/yr = 0.36 kg N/ha/yr reduction in N deposition due to NO_3. 3.1 (current) – 0.36 = 2.74 kg N/ha/yr by year 2012, which is close to the near term target load of 2.7 kg N/ha/yr.
- Given a 28% NO_x reduction by 2022, this would lower current deposition rate by 0.43 kg N/ha/yr, putting the wet deposition rate at 2.67 kg N/ha/yr.

These estimates, however, may overestimate the reduction in nitrogen deposition. As noted in the trends discussion, NH_4 concentrations and deposition have been increasing. If this trend continues, it would offset any benefits from NO_x emission reductions. It is also quite likely that some of the assumptions of linearity and uniform emission reductions are violated. For example, if the reactions are oxidant limited (which could be the case), the reduction would be less than 23%. Also, it is clear that the Front Range is not the sole contributor to deposition on the east side of RMNP, so to the extent that the

Front Range achieves greater NOx emission reductions relative to other regions, the benefits would be somewhat overstated. There are many uncertainties inherent in this calculation: there is no consideration of chemistry in this calculation, and there are inherent nonlinearities in NOx photochemistry.

On the other hand, other assumptions could lead to an underestimation of the reduction in N deposition. For example, if mobile sources along the Front Range are preferentially impacting RMNP, as opposed to other sources, then one might expect a greater reduction in N deposition because of the higher NO_x emission reduction expected from the mobile source sector (50-71%).

In short, the rate of reduction could be either high or low. Therefore, there is no guarantee that projected reductions will be sufficient to meet the 2012 interim target load, it is encouraging to note that significant progress toward the goal is reasonable to expect, based on this analysis.

In order to reach the resource management goal (critical load) of 1.5 kg N/ha/yr by 2032, an additional 44% reduction in combined NH3/ NO_x emissions would be needed. Since it appears that NH3 emissions currently contribute about half of the N deposited at RMNP, a 100% reduction in 2002 NO_x emissions from the Front Range, including metro Denver, would still not reach 1.5 kg N/ha/yr if NH3 emissions remain constant. NO_x reductions on the order of 30% are predicted by 2018 in other western and midwestern states as a result of regional haze plans. However, it is very likely that substantial reductions in NH3 emissions will be needed to achieve the resource management goal.

3. WRAP PSAT Analysis

The Western Regional Air Partnership (WRAP), over the past six years, has developed for application in the western United States, two sophisticated regional grid models designed to evaluate the effects of control strategies on regional haze. One of these models, the Comprehensive Air quality Model with extensions (CAMx), has the capability of tracking the contribution of individual sources or groups of sources to either ozone formation or particulate matter (PM). Recently completed PM Source Apportionment (PSAT) modeling "tagged and traced" SO_x and NO_x and NH_3 emissions from different states to RMNP, as well as other Class I areas, and reports on particle concentrations of NO_3 and NH_4 (as well as other pollutants). This modeling does not directly estimate source contributions to wet or dry deposition. However, it does indicate relative contributions of species related to deposition. The results of this modeling are available on the WRAP's Technical Support System website (http://vista.cira.colostate.edu/tss/Results/SA.aspx).

The state-by-state contributions of particle concentrations of various pollutants to RMNP were tracked with CAMx and plotted in the two pie charts below (Figures 13 and 14).

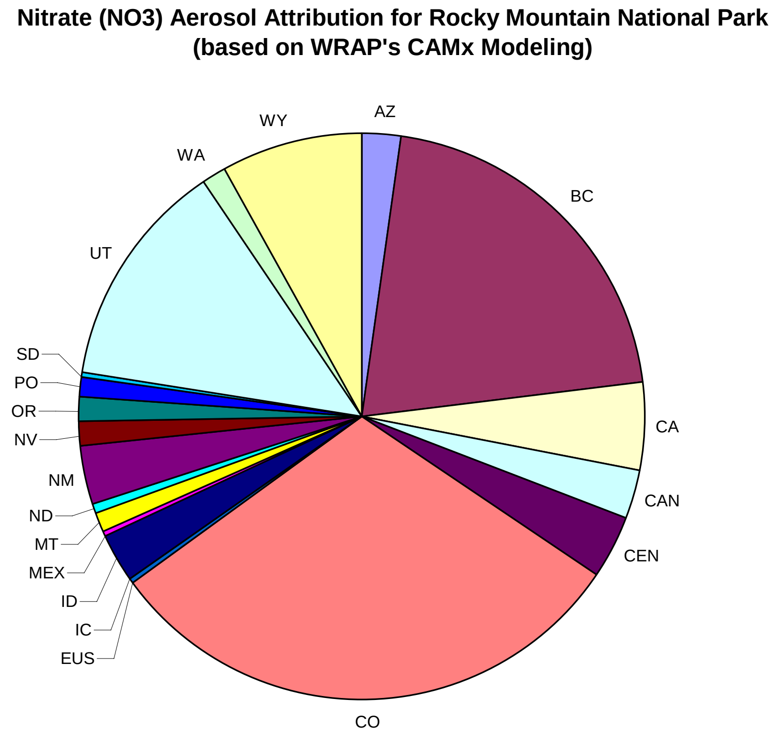

Figure 6. State Contribution to Annual Average Nitrate Airborne Concentration in Rocky Mountain National Park Based On CAMx.

Figure 6 shows that 31 percent of the particulate nitrate at RMNP is estimated to be from Colorado sources, on an annual average basis. The next largest sources are boundary conditions (BC), which are the emissions transported from the edges of the modeling domain over North America originating from all natural and anthropogenic sources. The next largest state contributions are from Utah, Wyoming, and California.

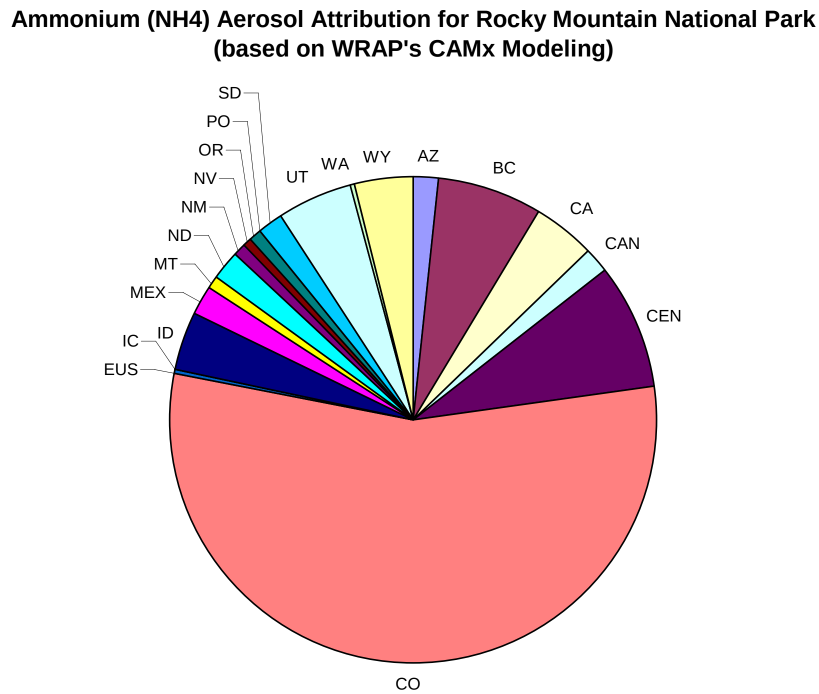

Figure 7. Source Contribution to Annual Average Ammonium Concentration in Rocky Mountain National Park Based on CAMx

Figure 7 shows that 55% of the particulate ammonium at RMNP is estimated to originate from Colorado sources, on an annual average basis. The next largest contributors, each contributing far less are the Midwest (CEN), boundary conditions (BC), Utah, and Wyoming.

The analysis also predicts apportionment by source type for NH_4 and NO_3 (see Figure 8). Of Colorado sources, approximately 10 percent of NH_4 comes from mobile sources and 45 percent comes from area sources, which includes agriculture. Midwestern states contribute, by comparison, less than 10 percent of area source NH_4.

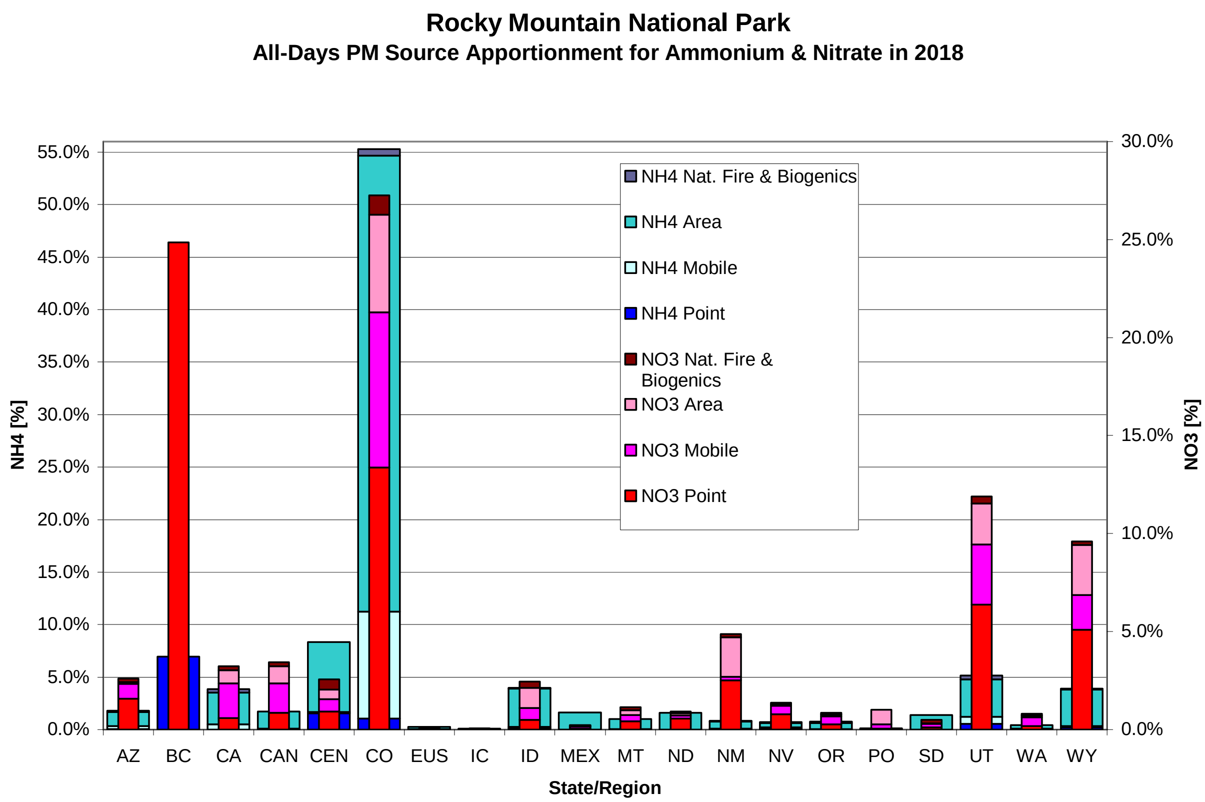

Figure 8

There are uncertainties with inferring deposition from a modeling analysis performed for the purpose of visibility assessment, but it is the best available analysis. Degraded visibility (high ambient particulate concentrations) and high wet deposition in a given geographic location may not occur simultaneously. Visibility is impacted by particulate air pollutants while deposition is due to pollutants in both particulate and gaseous form. Since WRAP's visibility assessment does not report the effects of changes of NO_x emissions on gaseous nitric acid concentrations or gaseous ammonia, this assessment does not present a complete picture of potential sources of deposition. Therefore, the Plan relies on this analysis as an indicator of the area or region of attribution and not as conclusive evidence.

4. Preliminary Analyses from the ROMANS Study

In an effort to further understanding of the origins of emissions currently affecting ecosystems and visibility in RMNP, a study is being conducted by a partnership led by the National Park Service.[18] The study is entitled Rocky Mountain Atmospheric Nitrogen and Sulfur Study (ROMANS). Two one-month intensive sampling periods were conducted in 2006, and analyses are underway to meet the following study objectives:

[18] Other partners are EPA, NOAA, USGS, USDA Forest Service, the Cooperative Institute for Research in the Atmosphere at Colorado State University, the State of Colorado's CDPHE, Air Resource Specialists, the University of California at Davis, and the Community Collaborative Rain, Hail and Snow Network.

- Identify the overall mix of sulfur and oxidized and reduced nitrogen in the air and precipitation on both the east and west sides of the continental divide.
- Identify the relative contribution to atmospheric oxidized sulfur and oxidized and reduced nitrogen at RMNP from emissions originating within the state of Colorado vs. outside the state.
- Identify the relative contribution to atmospheric oxidized sulfur and oxidized and reduced nitrogen at RMNP from emissions originating along the Front Range vs. other regions within the state.
- Identify the relative contribution of various source types within the state of Colorado to nitrogen and sulfur species, including mobile, agricultural, other area sources, and large and small point sources.
- Map spatial and temporal variability of atmospheric deposition within the park and relate observed patterns to likely source types and locations.
- Characterize the meteorological conditions that lead to various atmospheric and chemical conditions.

A preliminary ROMANS analysis examined how the simulation of airmass transport to RMNP differs between 36 km and 4km grid meteorological fields (MM5 wind fields). These differences may affect how source attribution results using 36 km wind fields (e.g. WRAP's PSAT) are considered. A more detailed report on this analysis is contained in Appendix A. This preliminary analysis—which was based on two weeks of wind fields (April 15 through April 30, 2006) —concluded that a 4km wind field estimates more easterly upslope flow than does a 36km wind field. A 4 km grid provides a more accurate analysis of the complex topography along the Front Range. The two week period of analysis did contain typical westerly transport as well as several upslope events, but is highly unlikely to represent all types of meteorological events that impact airflow over RMNP. Given this limitation, the results suggest that a 36 km simulation underestimates the contributions from sources east of the park including the Front Range. Since most of the emissions in Colorado occur east of RMNP, this suggests that a 36km simulation may underestimate the absolute contributions from Colorado sources to RMNP. Emissions from neighboring states to the east may also be underestimated. For the purposes of using the WRAP's PSAT analysis to infer deposition, it is possible that the reported contribution of Colorado sources represents a low-end estimate.

In the preliminary ROMANS analysis, the CAMx model was used to estimate the maximum potential concentration of nitrogen species at RMNP during the last two weeks of the Spring ROMANS field campaign. Two tracers, scaled to match the emission rates of NO_x and NH_3 in two scenarios were evaluated: 1) all tracer sources and 2) all tracer sources minus Colorado. The difference between these two scenarios represents Colorado's contribution relative to all other sources. During the two week simulation, about one-half of the NO_x tracer (Figure 9) and one-third of the NH_3 tracer (Figure 10) were attributed to Colorado sources. The relative contribution of Colorado to outside sources is a lower estimate. Since there is no removal of pollutants in the simulation, the emissions from very distant sources were able to travel to RMNP in this idealized simulation. Ammonia and the gaseous end products of the oxidation of NO_x emissions (nitric acid) would deposit relatively quickly and otherwise likely be removed before getting to RMNP. Therefore, this simulation suggests that the relative contribution from Colorado is underestimated. Even with the apparent underestimate, the Colorado contribution is significant.

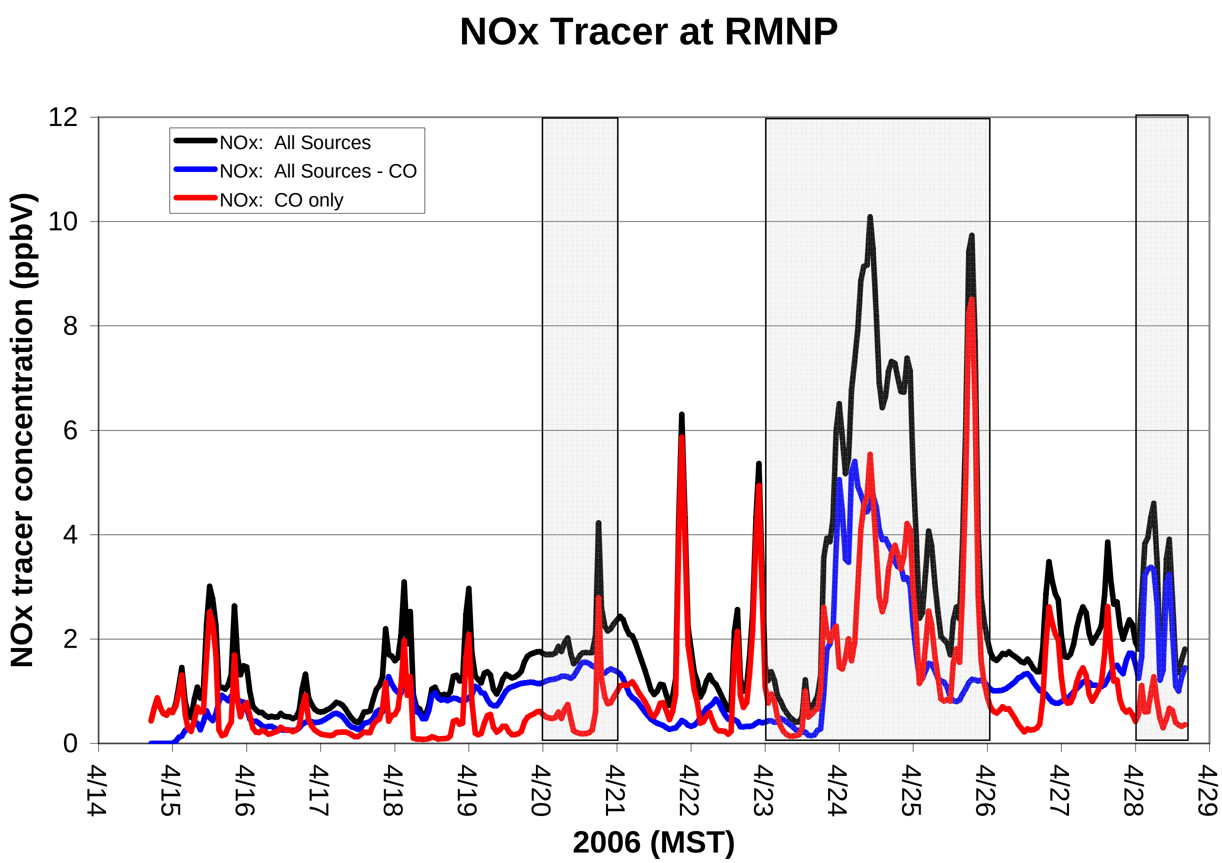

Figure 9

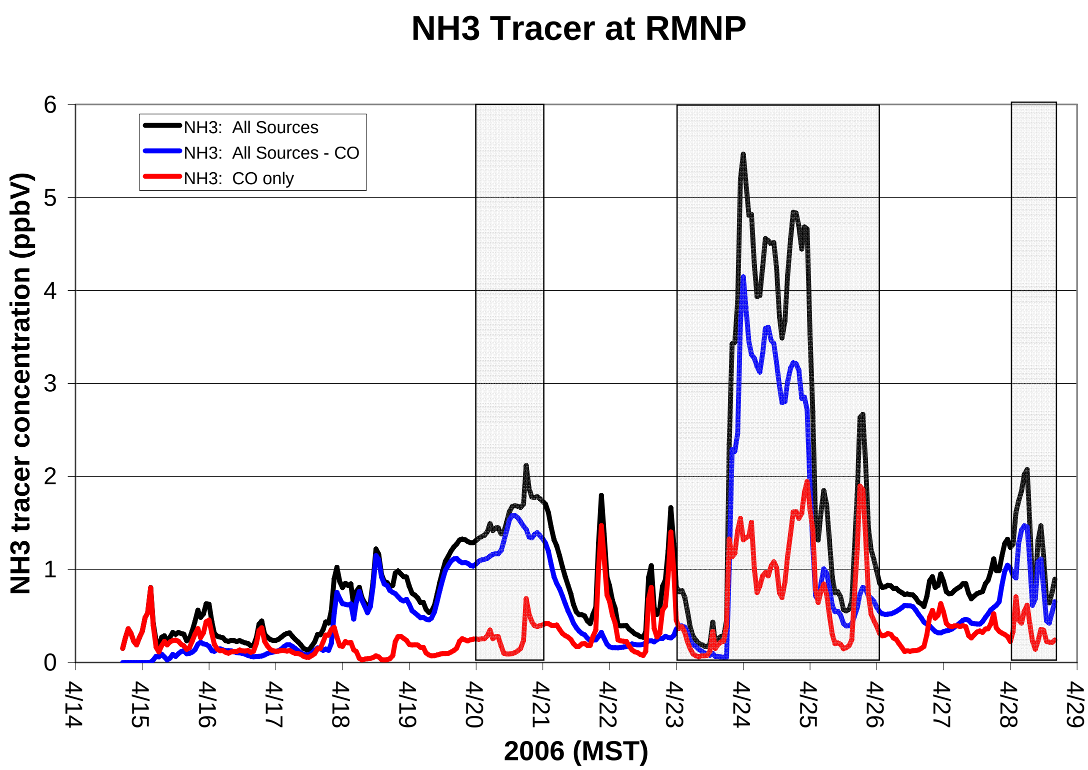

Figure 10

F. Questions to be Addressed by Data and Analyses

Throughout the process of the RMNP Initiative, AQCC Commissioners and stakeholders have posed various questions regarding emissions, deposition, attribution and implications of potential emissions reductions. The data and analyses discussed in this chapter was examined in the context of these questions, and the weight of the evidence used to provide answers to the greatest extent possible.

1. What benefits will planned emissions reductions have for nitrogen deposition loading and the increasing trend?

The rollback analysis described in section D.2, indicates we are likely to see some reductions in deposition from planned reductions, however the assumptions and uncertainties inherent in this calculation prevents making a specific prediction of reductions in deposition as a result of emission reductions.

2. How much of the nitrogen deposition loading comes from in-state vs. out-of-state?

The two analyses that partially address this question are the WRAP PSAT Analysis (section D.3.) and the Preliminary ROMANS tracer study (section D.4.). These analyses indicate that Colorado sources contribute a significant portion of the nitrate (>30%) and ammonium (>50%) found in fine particulates that affect visibility at RMNP. This does not explicitly apply to deposition, but a similar relationship may occur. The ROMANS tracer study modeling sensitivity runs, covering a two week intensive monitoring period using inert tracers to represent NO_x and NH_3 emissions, indicate that Colorado sources contribute significantly (>50% NO_x and >30% NH_3) to nitrogen concentrations in RMNP. The nature of this analysis (no deposition or chemical conversion) likely underestimates the relative contribution from Colorado.

3. How much of the nitrogen deposition loading comes from the Front Range and Metro Denver versus the rest of Colorado

Emissions data, monitoring data and preliminary ROMANS climatology analyses inform the question of source regions contributing to N deposition at RMNP. As shown in the emissions inventories above, approximately 63% of the state's NO_x and 44% of the state's NH3 come from Front Range counties (Adams, Arapahoe, Boulder, Broomfield, Denver, Douglas, El Paso, Jefferson, Larimer, Morgan, Pueblo and Weld). Ecological effects information, presented in Chapter III, also indicates that the ecological effects due to nitrogen loading are more pronounced on the east side of RMNP versus the west side.

In general, the highest NH_4 and NO_3 wet deposition at Loch Vale generally occurs during spring (March-April) and summer (July-August) (01-03 sampling) which are periods of the year that have frequent upslope meteorological conditions. Preliminary ROMANS analyses regarding particulate N concentrations and wind direction indicate that ammonium and nitrate peaks (in the summer campaign) are associated with upslope transport from the SE. Although this association doesn't distinguish between Front Range sources and the rest of Eastern Colorado, it does indicate a likelihood that Western Colorado sources have a lower contribution during short-term events (when NO_3 and NH_4 peaks appear to occur), but may contribute more over the long-term.

4. Can the contribution of different source categories (mobile, oil and gas, stationary, agriculture) to nitrogen deposition be identified?

Deposition budgets and trends, emission trends and WRAP's PSAT modeling are the primary sources of information that inform this question. The fact that at the Loch Vale site, NH_4 and NO_3 each contribute approximately equally to the mass of N deposited, implicate sources of NO_x and sources of NH_3 in equal amounts. The fact that NH_4 deposition is increasing faster than NO_3 would seem to indicate that NH_3 emissions are increasing faster than NO_x emissions, which appear to be declining. Because there are no reliable trends for NH_3 emissions, trends regarding the sources themselves may be relevant. Cattle and fertilizer appear to be on the decrease, while swine production has increased threefold in the last two decades in Colorado[19].

WRAP's PSAT analysis, Figure 15 (sectionD.3.), displays predictions for source contributions to particulate NH_4 and NO_3 concentrations in RMNP. Of the 55 percent of

[19] Ag statistical service reference needed

NH_4 predicted to be contributed by Colorado sources, 10 percent comes from mobile sources and 45 percent comes from area sources, including agricultural sources. Twenty-five percent of the NO_3 comes from point sources, 15 percent from mobile sources and less than 10 percent from area sources.

5. Are nitrogen oxides (NO_x) reductions equal to Ammonia (NH_3) reductions in decreasing deposition?

A reduction of 1 ton of ammonia is more effective than a 1 ton reduction of NO_x. As indicated in the molecular weight pie charts above, ammonia is 82% nitrogen by molecular weight; NO_x is 30% N by molecular weight. While there are more NO_x emissions along the Front Range and statewide than ammonia, and NH_4 and NO_3 contribute approximately 50% to the mass of N deposited at Loch Vale (NADP 2000-04 sampling), a ton reduction of ammonia should have a greater benefit.

6. If NO_x is decreased in the metro area, will ozone increase?

NO_x controls will lead to increased ozone in the local area of the controls due to the reaction of fresh emissions of NO with ozone ($NO+O_3 = NO_2 + O_2$). However, the effect farther down wind may be to reduce or increase ozone, depending on the chemical makeup of the atmosphere. Reductions in NO_x in areas where ozone concentrations are of concern generally need to be accompanied by further reductions in VOCs in order to make NOx controls at least ozone neutral. NH_4 decreases would have no impact on O3. Ultimately, modeling is needed to identify changes in O3 concentrations and the spatial extent and distribution.

7. How much additional reductions will be necessary to meet deposition goals? (emission-deposition relationship)

To meet the deposition goals discussed in section III, deposition of N would need to be reduced 13 percent by 2012, and 52 percent by 2032. In terms of emission reductions, there is insufficient information at this time to identify a specific emissions-deposition relationship for RMNP. The simplified calculation discussed above is subject to uncertainties. It is clear that to decrease N deposition in RMNP, NO_x and/or NH_3 emissions decreases need to occur. Studies and data discussed above indicate a strong possibility that the majority of deposition comes from east of the park.

8. What emissions come from inside Rocky Mountain NP? (in-park)

In general, in-park emissions are typically insignificant compared to local and regional emissions. Currently, there is no emissions inventory for all sources within the boundaries of Rocky Mountain NP. Section D.2. of this chapter discusses existing knowledge of in-park emissions and some strategies the park has taken to mitigate emissions. In addition, a Climate Friendly Parks Workshop" is tentatively planned for March, 2007 in the Park. This workshop, for park staff, will include development of an in-park inventory for criteria pollutants as well as greenhouse gasses (inventories do not typically include NH_3. As a part of the workshop, park staff will be assisted in identifying emissions reduction measures that could be conducted within park boundaries.

VII. Implementation Strategy and Continuing Evaluation

A. Introduction

Rocky Mountain National Park has developed a resource management goal for nitrogen deposition that is supported by the MOU agencies based on measurements and long-term research at the high elevation Loch Vale watershed. The resource management goal is expressed as a critical load at 1.5 kg N/ha/yr for wet nitrogen deposition (a 52% reduction from current wet deposition of 3.1 kg N/ha/yr).

The measured level of nitrogen deposition will serve as a basis for evaluating progress and taking future action. The Nitrogen Deposition Reduction Plan (NDRP) sets forth a glide path approach to achieving the resource management goal over a 25-year time period (by 2032) with interim milestones at 5-year intervals. The NDRP establishes a first milestone target load for wet nitrogen deposition in the Park at 2.7 kg N/ha/yr (a 13% reduction from current levels) to be achieved by December, 2012.

The NDRP primarily relies upon planned reductions and voluntary measures in the first planning period to reduce emissions that contribute to nitrogen deposition in RMNP. The consideration of enforceable control measures are contemplated in the context of the Regional Haze State Implementation Plan, but the NDRP primarily suggests voluntary rather than enforceable measures be adopted at this time.

The NDRP will be implemented by the MOU agencies working together in a collaborative fashion. The MOU agencies will review and incorporate new data and analyses; track and assess deposition in the Park and planned emission reductions; develop a contingency plan that could be implemented should the initial and any subsequent interim deposition goals not be realized and assess the need for future resources.

The MOU agencies will work together to revise the MOU consistent with this NDRP. The MOU agencies believe the collaborative effort should continue as the agencies work to achieve the emission reductions needed to reduce nitrogen deposition in the Park and protect a unique natural resource in Colorado. The MOU agencies will continue to collaborate with the Air Quality Control Commission and Water Quality Control Commission as forums for involving interested members of the public and seeking outside input.

B. Implementation Strategy

The overall strategy for reducing nitrogen deposition in RMNP is to reduce the emissions of nitrogen bearing compounds in Colorado. Further analysis may point us toward more specific source regions and categories. The strategy for achieving the first milestone primarily relies on the planned reductions of nitrogen compounds that are scheduled to occur through already adopted federal and state regulatory programs. In addition, the strategy also relies upon the actions of the agencies working with the agricultural community to identify new and broaden the implementation of existing agricultural Best Management Practices (BMPs). The following actions are identified and assigned to the MOU agencies working together or separately, as noted below, to reduce the emissions of nitrogen bearing air pollutants and nitrogen deposition in Rocky Mountain National Park.

1. NOx Emission Reduction Strategies

This Plan primarily relies upon currently implemented and promulgated programs as well as additional measures in the first planning period to reduce emissions that contribute to nitrogen deposition in RMNP. These programs will produce significant NOx emission reductions along the Front Range and through out the region during the first planning period. These programs include:

State measures:
- Diesel I/M
- Gasoline I/M
- State permitting requirements - NSPS, PSD, permit limits and standards
- BART regulations
- Repair your air program
- Woodburning restrictions
- Diesel school bus retrofits
- Summertime low RVP gasoline
- Alternative fuels programs
- Public information/outreach
- Rideshare/transit programs
- State tax credits for hybrids/alternative fuels use
- Xcel's Voluntary Agreement for metro power plants
- Craig, Hayden, Comanche reductions
- Winter fuel oil restrictions in metro Denver

Federal measures:
- Low sulfur diesel
- Low sulfur gasoline
- Off-road engine standards
- Diesel engine standards - TIER I, II, III
- Gasoline engine standards - TIER I&II
- Small engine standards
- Alternative fuels programs
- Federal tax credits for hybrids/alternative fuels use
- Clean Air Interstate Rule (not directly applicable to Colorado)
- NOx SIP Call (not directly applicable to Colorado)

Rocky Mountain National Park has implemented several emission reduction strategies that decrease the emissions of NOx within the Park, such as the Bear Lake Bus program, the use of biodiesel fuels and alternative fueled vehicles and more efficient technologies, and the implementation of additional Park shuttle bus services. The Park will continue to implement and evaluate additional mobile source strategies to reduce the emissions of NOx. The Park will also be developing an in-Park emissions inventory by the end of 2007.

In addition, the CDPHE , NPS and EPA are pursuing additional actions as noted below.

- CDPHE Air Pollution Control Division is currently evaluating NO_x emission reduction control strategies for proposed regulatory adoption as a part of the development of the Colorado regional haze state implementation plan. The Division will develop NO_x reduction control strategies for Park visibility improvements to be considered in the State's proposed Regional Haze SIP. The Division is working to develop a Regional Haze proposal that is slated for presentation to the Commission at their August 2007 meeting with action by the Commission anticipated by the end of 2007.

- NPS Air Resources Division will work to negotiate mitigation strategies including offsets with new sources in the context of the Prevention of Significant Deterioration program. Additionally, NPS will seriously consider whether new and modified PSD sources of nitrogen compounds would adversely impact air quality related values at RMNP.

- EPA Region 8 will provide additional technical assistance to the state on review of new or modified PSD permit evaluations. EPA Region 8 will provide expertise on control technology associated with permits and State Implementation Plans (SIPs) , including the Regional Haze SIP. EPA will seek out opportunities for federal financial assistance to support analysis and data gaps for the RMNP Initiative.

2. Ammonia Emission Reduction Strategies and On-Going Research

Ammonia emissions contribute significantly to nitrogen deposition in RMNP. However, it is recognized by the agencies that ammonia emission controls are not as well developed as emission controls for the emissions of NOx, especially the emissions of NOx from stationary sources. Ammonia emissions are generated from a variety of sources, but primarily from the use of fertilizers in cropping systems and urban settings and the management of waste from livestock production. The MOU agencies recognize that there is much work to be done to research and develop best management practices that can be implemented to address these sources of ammonia and that some management practices are currently being implemented that help to reduce the emissions of ammonia. The NDRP relies upon the continued implementation of currently used BMPs and the ongoing effort to identify and implement new BMPs that can help to reduce emissions of ammonia. Below is a set of strategies that the agencies believe will help to reduce nitrogen deposition in RMNP.

The MOU agencies will work with the agriculture stakeholders during 2007 – 2012 planning period to promote and broadly implement best management practices that are now being implemented to some degree in Colorado. These BMPs are discussed in Chapter V.B. of this Plan and include:

Crop production
- Conservation tillage
- Appropriate fertilizer selection
- Fertilizer application rate management
- Fertilizer placement techniques
- Proper fertilizer storage and handling

Livestock Production
- Reducing dietary crude protein
- Phase feeding
- Barn design
- Land application of manure techniques
- Pasture management techniques

The following describes the ammonia emissions and agricultural BMP research and evaluations that will occur over the next 5-year period.

a. Ammonia Emission Inventory Improvements and General Mitigation Option Development

- CDPHE will work to improve the NH_3 inventory assumptions and improve the accuracy of the agricultural NH_3 inventory.
- CDPHE will work to update the Colorado Ammonia Emissions Inventory to include Front Range urban and municipal sources of potentially volatile nitrogen applications to lawns, parks, golf courses, and open spaces in foliar and granular forms from both commercial and non-commercial application methods. Mitigation strategies will also be developed.
- CDPHE will work to improve emissions estimates and develop mitigation options from landfills, garbage dumps and other potential ammonia emission source not adequately characterized in Colorado.

b. Livestock and Crop Production Trends

- CDPHE will work with the agriculture workgroup and the Colorado State University Agricultural Extension to forecast future trends in livestock and crop production.
  - The first draft of this task should be completed by 10/31/07.

    - New information will be factored in as it becomes available.

c.Agriculture BMP Research Program and Implementation

- CDPHE will work to form a Technical Team to include MOU agencies and Colorado's agricultural industry (Colorado Livestock Association, Colorado Farm Bureau, Colorado Cattlemen's Association, Rocky Mountain Farmer's Union, Colorado Corn Grower's Association, Colorado State University, Colorado Department of Agriculture, Natural Resources Conservation Service, et. al.) which will:
    - Coordinate research review between the MOU agencies and the agricultural community;
    - Address air quality issues and review research related to ammonia emissions, greenhouse gases and national ambient air quality standards from livestock and crop production activities and related best management practices;
    - Incorporate the final best management practice research results into technical standards and technical service advisories put forth by the Natural Resources Conservation Service; and
    - Identify and develop incentives for existing programs to provide additional resources, both financial and technical, to agricultural producers to implement and expand their use of voluntary, proven best management practices.

- Develop and conduct a survey of current Best Management Practices:
    - The survey is to be conducted by CDPHE and Colorado Agriculture organizations working with Colorado State University.
    - The survey will identify existing BMPs being used by livestock and crop producers in Colorado, and is planned for completion by ___.
    - CDPHE and Colorado agriculture organizations will work with Colorado State University to conduct a management practices survey of Colorado livestock producers and crop producers.
    - CDPHE and the Colorado agricultural organizations will promote a prompt producer response to the management practices survey, as well as work with Colorado State University to create a database of agricultural BMPs from the results of the survey data.
    - The survey will also be shared with neighboring states (such as Kansas and Nebraska) for implementation.
    - Colorado State University will incorporate the survey findings into their evaluation of the most effective and appropriate best management practices for ammonia reduction that will be studied during a Colorado based on-farm Best Management Practices evaluation. During this phase of this project, CDPHE and Colorado agriculture organizations will provide assistance to Colorado State University, as practical and feasible. This work will begin in 2007 and will continue into 2008. If further

funding is acquired, additional on-farm testing will take place in 2009 and beyond.

- CDPHE, Colorado State University and Colorado's agricultural industry will work to implement agricultural best management practices that are based on economically viable, field-tested and provide proven ammonia emissions reductions. Implementation of best management practices will be promoted by CDPHE, and implemented by Colorado's livestock and crop producers, on a voluntary basis.

- CDPHE and the Colorado agriculture organizations will work with state and federal agencies to identify and develop incentives for existing programs to provide additional resources, both financial and technical, to producers to implement and expand their use of voluntary, proven best management practices.

d. <u>EPA's Animal Feeding Operations (AFO) Air Quality Compliance Agreement.</u>

- In January 2005, The Environmental Protection Agency announced an air quality compliance agreement to address emissions from egg, chicken, turkey, dairy, and swine industries, to ensure compliance with applicable CAA, CERCLA, and EPACRA provisions. Over the next several years there will be monitoring and evaluation of AFO emissions, to develop methodologies for estimating more accurate emissions from AFOs. This agreement and corresponding emission information will provide additional data for estimating emissions from agricultural operations.

3. Additional Agency Actions

The following describes the additional policy development and evaluation activities that will occur over the next 5-year period by the MOU agencies.

a. Education and Outreach

- CDPHE and Colorado agriculture organizations will partner with Colorado State University to develop an education and outreach strategy to inform agriculture producers about the concerns related to Rocky Mountain National Park and the value of best management practices in reducing environmental impacts to the park. To this end, CDPHE, Colorado State University and Colorado agricultural organizations will work together to develop an education and outreach strategy for agriculture.

- The outreach strategy will include recommendations on how to best provide information to the agriculture community in a phased implementation approach (as information on best management practices become available); identification of potential funding mechanisms; suggestions of potential partners for leveraging resources; recommendations on a process for tracking implementation of best management practices, including information on environmental outcomes where practical; and recommendations on developing a plan to communicate and coordinate with other states on ammonia issues impacting Rocky Mountain National Park.

- CDPHE, Colorado State University and Colorado agricultural organizations will work with the United States Department of Agriculture's Natural Resource Conservation Service to incorporate the final best management practice research results into technical standards and technical service advisories put forth by the Natural Resources Conservation Service.

- RMNP will continue interpretation and outreach activities to educate others on nitrogen deposition and the NDRP.

b. Coordination with Other States

- The MOU agencies, in conjunction with the agriculture workgroup, will explore strategies other states (and other countries if applicable) are using to track and manage ammonia emissions. The Idaho program will be included in a report to be completed by 12/31/07.

- The MOU agencies will work to implement an interstate dialogue and control program on nitrogen emissions coming into Rocky Mountain National Park from other states, as appropriate.

c. Material Use and Throughput Reporting

- The MOU agencies, in conjunction with the agricultural workgroup, will explore the potential of a reporting requirement for tracking BMP implementation, fertilizer use, waste management practices, feed use, or any other measure of activities that create NH_3 emissions. This data collection would be for the purpose of tracking potential NH_3 emissions in the absence of monitoring actual NH_3 emissions from a particular facility. A report on this issue will be prepared by 3/31/08.

d. Contingency Plan

- The MOU agencies believe careful attention to implementation of emission reduction strategies, tracking emissions and deposition, and contingency planning will be necessary to achieve resource protection milestones in RMNP. The agencies will work in the near term to develop a contingency plan to be implemented should the NDRP fail to achieve interim milestones, with the intent of achieving the desired goals within the planned timeframes. The contingency plan will account for implementation strategies during periodic reviews of progress measured against the glide path, and adjustments in implementation of strategies made to ensure goals are met.

- CDPHE will lead an effort to analyze the NO_x strategies in Table V-2 and listed below, should the NDRP fail to achieve any of the interim milestones. The analyses and contingency plan will be developed by 12/31/09 and presented to the AQCC in 2010 for their approval.

    - SCR or SNCR on New or Existing EGUs and Boilers
    - LNB or ULNB on New or Existing EGUs and Boilers
    - NSR LAER and Offsets for Major Sources Statewide
    - Controls on Non-BART Major Sources and BART-eligible Sources not Subject to BART
    - NO_x Emissions Cap and Trade Program
    - P2 and Voluntary Reductions
    - Alternative, Renewable, or Energy Efficient Requirements
    - Local VMT Reductions
    - EPA Hydrocarbon/Nitrogen Oxides Cutpoints into Inspection and Maintenance Program
    - Inspection and Maintenance to Control nitrogen oxides for Metro Denver and North Front Range
    - Dirty Screen RSD with Enhanced Inspection and Maintenance
    - Dirty Screen RSD without Inspection and Maintenance
    - On-Board Diagnostics
    - Address Vehicles that Never Pass I/M240 After Failing Test
    - New Vehicle On-Road California LEVII Tailpipe Standards
    - Off-Road and Small Engine California Standards
    - State-wide New/Existing Engine Controls
    - Minor Source New/Existing BACT for Natural Gas Compressor Engines (greater than 100 hp).

- CDPHE will lead an effort to analyze and evaluate sources of ammonia including urban and agricultural for additional reductions should the NDRP fail to achieve any interim milestones. The MOU agencies, in conjunction with the agriculture workgroup, will explore whether Housed Commercial Swine Feeding Operations, as defined in CRS §25-8-501.1(2)(b), represent a significant ammonia emissions source category and whether potential emissions reduction strategies exist.

- If voluntary emissions reduction measures do not result in deposition reductions in the Park to meet the resource management goals set for 2012 and in subsequent 5-year intervals, additional voluntary and enforceable measures will be developed and proposed for consideration.

e. Legal and Policy Initiatives

- The MOU agencies will work together to identify future legal and policy issues as they act to implement this Plan. The agencies will discuss legal and policy issues internally and propose responses to issues in a public forum to gather citizen input and participation. Legal issues regarding authority of an agency to act may require legislative proposals to be made at the State or Federal level. None of the MOU agencies are bound by the NDRP or its implementation to share, divulge, or discuss legislative initiatives they may choose to pursue, but are encouraged to provide information as they deem appropriate.

f. Pollution Prevention

- The MOU agencies will seek the guidance and input of the Colorado Pollution Prevention Advisory Board to develop concrete methods to encourage voluntary emission reductions or other approaches to reduce emissions of ammonia and oxides of nitrogen especially along the Front Range. The CDPHE Sustainability Program may be able to assist in the development of cross media approaches to reduce emissions while achieving several objectives.

g. Water Quality

- The MOU agencies, in collaboration with the Colorado Water Quality Control Commission, will continue to track and assess water chemistry and aquatic biota data in the Park to determine whether any regulatory actions - discussed in chapter 5 of this plan - are necessary or useful in protecting potentially impaired waters in the Park.
- CDPHE will examine the potential nitrogen emissions, and the contribution to nitrogen deposition in RMNP, from the treatment of ammonia in municipal waste water treatment plants. CDPHE will also identify options to mitigate such impacts.

h. Deposition Monitoring, Research and Modeling

- RMNP, along with its partners, will continue to monitor nitrogen deposition levels and other air quality constituents during the life of this Plan incorporating new technologies when proven accurate and reliable.

- NPS will continue to analyze and interpret monitoring data; to report annual trends and the status of existing air quality in the Park; to collaborate with universities and agency partners on ecological effects research in the Park; and in the context of the regional haze plans, will engage in interstate consultation on the issue of nitrogen deposition.

- The National Park Service Air Resource Division will lead the effort to complete the Rocky Mountain Atmospheric Nitrogen and Sulfur (RoMANS) study. The RoMANS study should help develop the understanding of how to attribute sources of emissions to the overall deposition of nitrogen in the Park. This study will be completed by ___ and results will be incorporated into evaluations presented to the AQCC in the 2-year reporting timeframes. During the RoMANS study period, and any subsequent studies, the NPS will work to conduct further refinements and improvements to the technical model in order to reduce uncertainties regarding transport.

i. National Issues

- EPA Region 8 will provide input to the national program and on national workgroups for rulemaking or policy initiatives that may impact RMNP air quality. (e.g. NOx PSD increment standards, PM10/PM2.5 standards, Regional Haze implementation, Critical Loads application and approach , NOx control emission standards)

C. Continuing Evaluation

- The MOU agencies will evaluate the reductions in nitrogen deposition as the data are collected throughout the first planning period. The MOU agencies will present this evaluation to the Air Quality Control Commission in 2 year intervals; the first to occur before the end of 2008. The MOU agencies believe that more frequent evaluation will be necessary to gage progress, especially in the first planning period. These biennial evaluations will be indications of progress toward the achievement of the first interim milestone in 2012. As the agencies work to implement the NDRP, they will consider revision of the resource management goal beyond the 1.5 kg N/ha/yr as a margin of safety to ensure ecosystem protection. Below is a table of the interim milestones.

2012	2017	2022	2027	2032
2.7 kg N/ha/yr	2.4 kg N/ha/yr	2.1 kg N/ha/yr	1.8 kg N/ha/yr	1.5 kg N/ha/yr

- The MOU agencies will work to assess the effectiveness of ammonia BMPs. The agencies will report on the effectiveness of the BMPs that have been implemented by December 31, 2010. This report will include an analysis of the projected benefits of the ammonia emission reductions and whether or not additional ammonia emissions reductions (voluntary or regulatory) are needed to achieve the 2.7 kg/ha/yr, 2012 interim milestone and a plan to achieve those reductions.

- If voluntary emissions reduction measures do not result in deposition reductions in the park to meet the resource management goals set for 2012 and in subsequent 5-year intervals, enforceable measures will be proposed.

- The MOU agencies will work together to identify future legal and policy issues as they act to implement this Plan. The agencies will discuss legal and policy issues internally and propose responses to issues in a public forum to gather citizen input and participation. Legal issues regarding authority of an agency to act may require legislative proposals to be made at the State or Federal level. None of the MOU agencies are bound by the NDRP or its implementation to share, divulge, or discuss legislative initiatives they may choose to pursue, but are encouraged to provide information as they deem appropriate.

- NPS will continue to analyze and interpret monitoring data; to report annual trends and the status of existing air quality in the Park; to collaborate with universities and agency partners on ecological effects research in the Park; and in the context of the regional haze plans, will engage in interstate consultation on the issue of nitrogen deposition.

- CDPHE will evaluate the mobile source emission reductions to better determine the impact that they are projected to have on the reduction of nitrogen deposition in RMNP.